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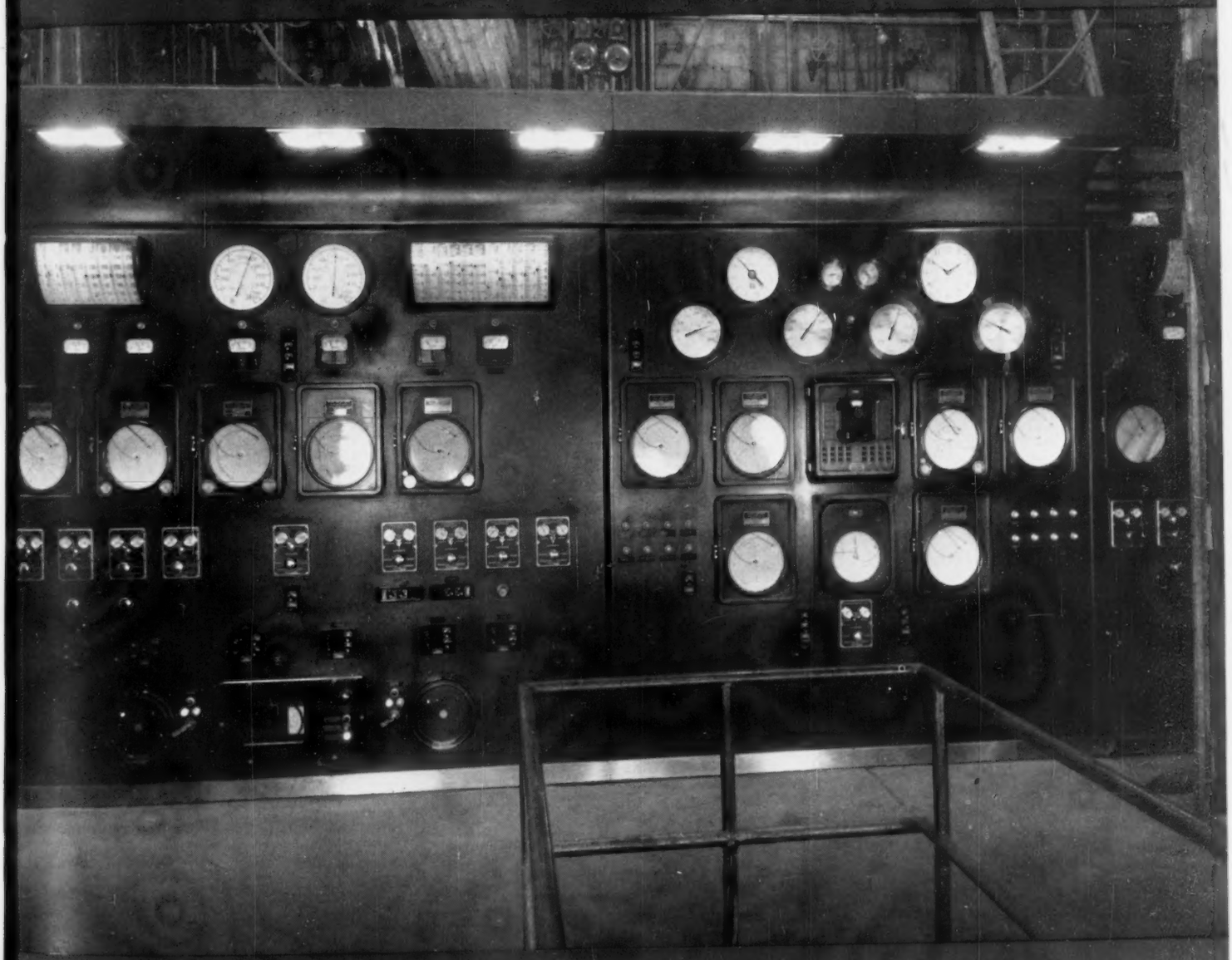
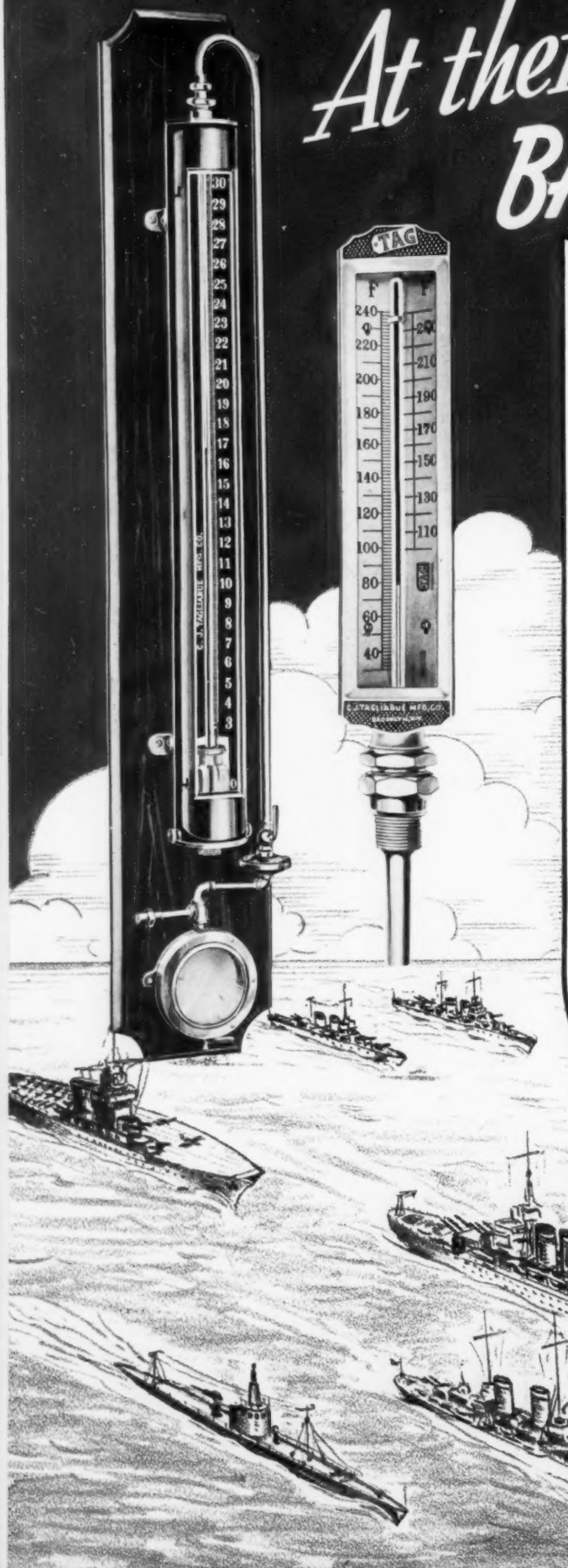


INCLUDING Aviation Instruments

At their BATTLE STATIONS



TAG THERMOMETERS and INDUSTRIAL INSTRUMENTS ARE SERVING THE NAVY

Thousands of these sturdy TAG Instruments go to sea today with America's ever-expanding naval armada . . . accurately indicating that important measurement—TEMPERATURE—on all types of warcraft, from submarines to battleships. In the boiler room, on propulsion machinery, refrigeration systems, pumps, turbines and Diesel engines, they are playing their part, contributing to the effectiveness of our naval striking forces.

Pounding naval action naturally places a heavy strain on the precision of temperature indicating instruments, but there's no excuse for failure when the chips are down and lives are at stake. TAG Instruments are made to meet the exacting specifications of the Navy. They have had to prove, under the sternest tests, that they can take the terrific vibration and concussion of battle conditions and maintain vital accuracy.

On the Home Front, in thousands of industrial plants, where the sinews of war are being forged and fabricated, these same TAG Instruments are at their "Industrial Stations" where they have served so faultlessly for generations. Their superior strength, matchless sensitivity and easy readability recommend them particularly in the service of war goods production. Ask us to demonstrate what they can do for you.

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Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

Hail the American Association for the Advancement of Science!

INSTRUMENTATION—and Science and Industry, as well as the War Effort—owe a debt of gratitude to the AAAS (and to Dr. Neil Gordon in particular) for the Association's decision to schedule Instrumentation as the theme of the final Gibson Island Conference of 1942. These Conferences are informal; no "Proceedings" are published; nothing is sponsored; no statements are made "for the record" and such lectures as are published in scientific and technical magazines must not mention the Association. Result: utter freedom of discussion and perfect friendship between champions of opposite views. Further result: *advancement* of Science.

More than that, your editor hesitates to write "for the record" at this time. The Association has not yet issued a publicity release. However, we are sure it is permissible to inform *Instruments* readers that the program published on this page last March was followed fairly closely in spite of war-caused absences; that there will be a one-week Conference in August 1943; and that those in charge are:

Gen'l Chairman, Neil Gordon, Central College, Fayette, Mo.

Instrumentation Conference Chairman, J. J. Grebe, Dow Chemical Co., Midland, Mich.

Vice-Chairman, W. G. Brombacher, National Bureau of Standards, Washington.

We asked the still camera hounds to rush their best shots to us (we were one of the movie-cam hounds) but, as we go to press, the only one to make the dead-line is J. G. Ziegler, whose shot is reproduced below.

And from 1942 Vice-Chairman Rimbach, we have obtained the following list of Participants:

Ackerloff, G. C., Montsanto Chemical Co.
Barstow, Ormond, Dow Chemical Co.
Behar, M. F.*, Instruments Publishing Co.
Brewer, Nathaniel, Fischer & Porter Co.
Bristol, E. S., Leeds & Northrup Co.
Bristol, R. A., Foxboro Co.
Brombacher, W. G.*, National Bureau of Standards
Calder, Douglas S., Forest Products Chemical Co.
Caldwell, Smiley, Adamston Flat Glass Co.
Connor, W. P., Hercules Powder Co.
Cope, J. H., Merck & Co.
Crouch, Harold W., Eastman Kodak Co.
Darnell, R. C., Ordnance Dep't, U.S. Army
Deane, C. W., Merck & Co.
DeJuhasz, K. J.*, Pennsylvania State College
Draper, C. S.*, Massachusetts Institute of Technology
Eckman, D. P., Brown Instrument Co.
Eskin, S. G., Robertshaw Thermostat Co.
Ewald, Philip, Tennessee Valley Authority
Fairchild, C. O.*, C. J. Tagliabue Manufacturing Co.
Gordon, Neil E., Central College
Gray, T. S.*, Massachusetts Institute of Technology
Grebe, J. J.*, Dow Chemical Co.
Harrison, T. R., Brown Instrument Co.
Hartline, R. E., Mine Safety Appliances Co.
Heinz, W. B.*, Calco Chemical Co.
Hildebrand, John G., Jr., Gustavus J. Esselen, Inc.
Homan, John G., Davison Chemical Co.
Jonnard, R., Warner Institute for Therapeutic Research
Keppler, P. W.*, Sanderson & Porter Co.
Kniazuk, Michael, Merck Institute for Therapeutic Research
Landis, Quick, New York City
Lantz, D. L., Adamston Flat Glass Co.
Limont, A. W., Barrett Division
Lyons, James, Southern Regional Research Laboratories
Mabey, C. A., Bristol Co.
Malin, J. B., Texas Co.
Mason, C. E.*, Mason-Neilan Regulator Co.
Mason, H. L., Taylor Instrument Co.
McKinney, Alfred H., Philadelphia Quartz Co.
Molsted, M. C., University of Pennsylvania
Nichols, N. B.*, Massachusetts Institute of Technology
Noyes, Bradford*, Taylor Instrument Cos.
Peters, J. C.*, Leeds & Northrup Co.
Pompeo, D. J., Shell Development Co.
Rimbach, Richard, Instruments Publishing Co.
Rockwell, Harvey*, War Production Board
Smith, Ed S., C. J. Tagliabue Manufacturing Co.
Walden, Jr., G. H., Esso Laboratories
Wannamaker, W. H., Brown Instrument Co.
Webb, R. D.*, Carbide and Carbon Chemicals Corp.
Ziebolz, H.*, Askania Regulator Co.
Ziegler, J. G.*, Taylor Instrument Cos.
Zucrow, M. J.*, Elliott Co.

*Lecturer.

(Photo by Ziegler)
Fairchild Lyons Calder Peters Rimbach E.Bristol Landis Noyes Jonnard Darnell
Harrison Grebe Molsted Gordon Deane Homan Cope R.Bristol Keppler Hartline Mabey Pompeo Webb Heinz Limont
Caldwell Malin Eskin Brombacher C.Mason Draper Smith Behar DeJuhasz Ziebolz McKinney Nichols Ewald Crouch

Richard Rafferty checks an instrument at the Bureau's test table.

In the office of M. L. Clarke (right), J. M. Hudack inspects a Strobotac.

Bell Telephone Laboratories' Central Instrument Loan System

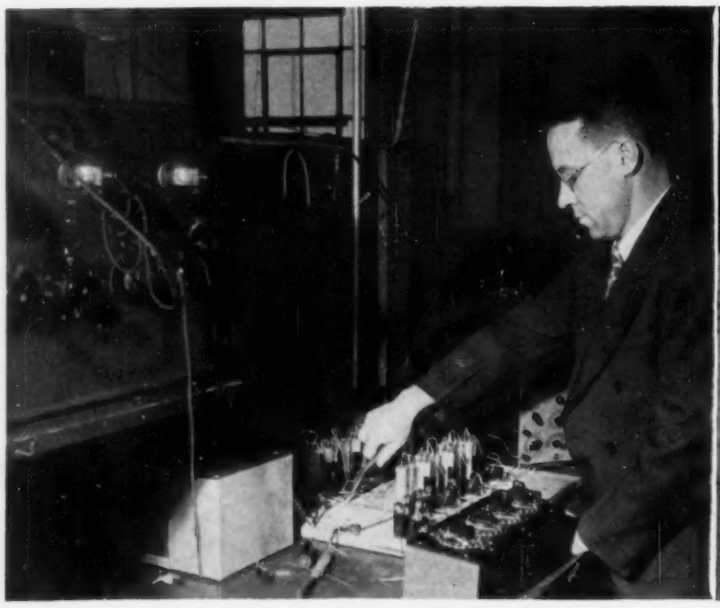
By M. L. CLARKE

In Charge of Instrument Bureau, General Service Dep't., Bell Telephone Laboratories

TO provide twenty-five hundred Research Engineers with measuring instruments is a major problem. For many years Bell Telephone Laboratories has handled it by the dual method of assigning permanently to certain groups instruments which are in constant use by them, and by establishing, in addition, a Central Instrument Bureau from which other instruments may be borrowed temporarily. This system permits handling expeditiously peak demands for standard equipment and it decreases the total investment in measuring instruments. Special instruments not in continuous demand by any one engineer, but which are needed on short notice from time to time by different groups, are also in the custody of the Central Instrument Bureau.

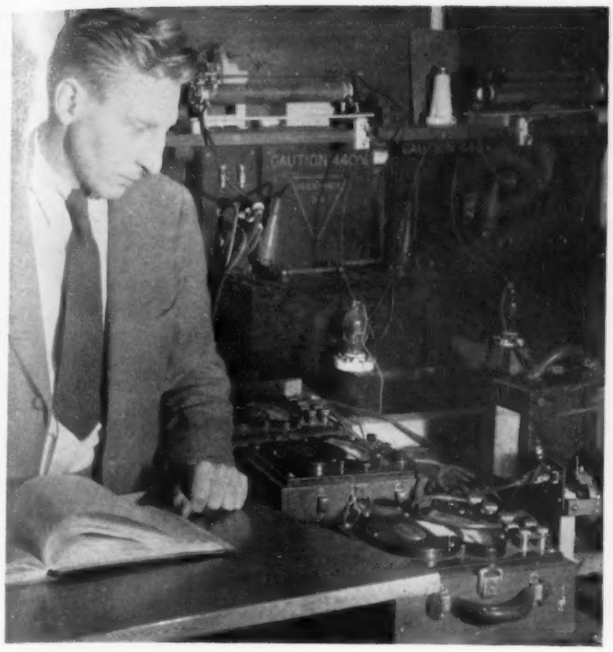
Included in the collection are about three thousand separate items, among them ammeters and voltmeters of various ranges, rheostats, bridges, galvanometers, potentiometers, tachometers, thermometers, pyrometers, oscillators, stroboscopes and noise measuring sets.

The instruments are catalogued and stored in accessible locations under the care of a custodian. A card file of all the instruments is maintained and a follow-up system keeps track of each item on loan.



The attenuator box in the foreground was drawn from the Central Instrument Bureau for an experiment having to do with submarine telephone cables.

Measuring the voltage required to break down an oxide coating on aluminum is part of a reliable method for measuring the thickness of such coatings.



Instruments permanently assigned to the Transformer Development Group are recorded in the Central Instrument Bureau and can be borrowed by other groups when necessary.

Laboratories' engineers sent out to test initial installations of Bell Labs developments carry a full complement of instruments drawn from the Bureau.

Instruments are checked for accuracy when returned from a loan and tagged with the date of recalibration. Minor repairs are made by the Bureau; others by the manufacturer or his agent. Resistances, capacitor boxes and slide-wire rheostats are cleaned and polished before releasing them again. Periodic checks are made of batteries, bridges, also of vacuum tubes in voltmeters, oscillators, oscillographs and stroboscopes.

Instruments are loaned for relatively short periods and about 85% of the entire stock is in circulation all of the time. At the expiration of the agreed loan time, instruments not returned are followed up to make them promptly available for others.

A file is kept by identification number and alphabetically by function of laboratory apparatus and instruments purchased by all departments of the Laboratories. Many of these can be made available for short periods to other engineers than those to whom they are assigned. When an instrument in this category is requested which is not in the Central Bureau collection, this file is consulted and arrangements can often be made to borrow it temporarily for a specific use.

Requests for special instruments or for generally used instruments not normally available are reviewed by a committee of the Instrument Bureau, which meets as the needs warrant. When the purchase of special instruments is advisable or the number of requests indicates that more regular instruments are needed, recommendations to this effect are made for their purchase by the Instrument Bureau.

As new instruments are developed and placed on the market, the committee also investigates them and recommends the purchase of those items which in their judgment will meet definite needs in the Laboratories and thus warrant the expense involved.

With all types of instruments now in abnormally great demand for the many war projects on which the Laboratories' staff is now engaged, and with new instruments now difficult to obtain, the central instrument loan system has contributed increasingly valuable help toward expediting this urgent work.

Miss Phyllis Barton checks records to determine the location of an instrument on loan.

Joseph Gramels of the Repaired Apparatus Department asks a temporary loan of a Wheatstone bridge from John Stelljes.

Characteristics of Hydraulic and Pneumatic Relays as Energy-converting Devices

By HERBERT ZIEBOLZ
Vice-President, Askania Regulator Co., Chicago, Ill.

EDITORIAL FOREWORD

IN this article and in the one (or those) to follow, one of the keenest analytical minds in the field of instrument engineering points out the essential functional similarities of relay devices which differ so widely in their appearance and in their "engineering" characteristics that they usually are considered entirely different.

Seldom if ever have so many disclosures about relay-type instruments been condensed into a few thousand words and a few dozen simple sketches.

Seldom if ever has there been published such an easily-understood and yet penetrating introduction to what is really a complex subject—in fact a series of ten subjects in the Science of Instrumentation—the subjects of

Measurable Magnitudes	Amplifiers
Utilizable Effects	Follow-ups
Primary Elements	Feedbacks
Prime Relays	Dampers
Subordinate Relays	Servo-motors

(*To Non-mathematical Readers*—This presentation IS easily understandable. Don't let the math symbols throw you. All you need remember is that if S, for example, is a change of position then dS/dt means the rate of change, or the speed—just like the speed of a car; and d^2S/dt^2 simply means the acceleration—just like the "pick-up" of a car.)

This probably is the first approach to these subjects which UNIFIES them. Ziebolz unifies them by lumping under only two categories all the numerous conceptual entities and all the numerous tangible things which are involved. One of his two categories is "energy conversion" which includes multiple stages as well as single stages and which he treats algebraically. (In fact, the original title of his manuscript was "Hydraulic and Pneumatic Relays for the Solution of Algebraic Equations.") His second category consists of the things, namely "relays." In this broad category he includes devices universally known as relays and he selects for emphasis the hydraulic and pneumatic types, but he includes also primary measuring elements—and even such simple things as levers—and other instrument parts which fall outside of the "relay" category in the "formal" or "official" science of Instrumentation.

In the history of science and engineering, almost every new unitary approach to a plurality of subjects was even more difficult to clothe in a correct vocabulary without ambiguous terms and symbols than it was to conceive. This presentation is no exception. Because it is so original and because it cuts across so many boundaries, it either had to include new words (requiring explanations), or else it had to violate the terminology of Instrumentation. With a modesty that concealed the grasp of English he acquired since coming to this country, the author asked the editor to make ALL terms conform to the terminology of Instrumentation. This probably could not have been done, however, without needlessly lengthening too many of the author's crisp, concise and sufficiently-intelligible statements.

(Read for example the first five lines of the second column on page 341. Imagine the consequence of deleting "units" and substituting a boresome differentiation between "that-which-is-yet-to-be-measured" and the *result* of "converting" a "magnitude" into a "quantity" by "utilizing" a "continuous-series" "effect" permitting the establishment of a "scale law" and hence of a scale divided into units!)

It probably could not have been done without re-writing most of the whole presentation including the article (or articles, we hope!) which are to follow—of which we have had a glimpse. It probably could not have been done without altering and amending and twisting not only words but meanings, not only sentences but ideas, not only the verbal clothes but the body and soul of Ziebolz's brain-child.

—M. F. BEHAR

SUMMARY

THIS article discusses briefly some of the characteristics of present relay devices. After introducing as equivalents the "F.P.S." system, representing Forces, Pressures, and Strokes, which control the relays, it shows how by means of relay valves any one of the systems can be translated into any of the other systems.

As relay devices are to be considered as energy flow controllers, the "F.P.S." values are shown to be indices of energy values.

It is further shown that most algebraic equations can be solved rather easily by such devices.

The article ends with the discussion of some recent developments in the application of relays to the solution of $\frac{d(\text{F.P.S.})}{dt}$ and $\frac{d^2(\text{F.P.S.})}{dt^2}$ values.

The bewildering number of new control devices and control circuits brought out in recent years—a number which after the war will be increased by the application of military devices for peace-time use—made it desirable to reduce them to basic units.

Once such units with definite characteristics are established, it is much easier for the engineer to analyze control circuits as he can—at least for the purpose of understanding the general over-all picture—forget the details of the individual design.

The advantages of such an approach are evident in the field of electricity, where certain types of tubes—such as triodes, thyratrons, pentodes, etc.—become units in themselves and do not call for an individual description or explanation.

The designer as well as the industrial control engineer and—last but not least—the patent engineer, also profit by this simplification insofar as it avoids the necessity of detail work which is only a repetition of routine engineering. It is surprising to see particularly in the *Patent Office Gazette*, how time and again the same basic idea is patented in the guise of a new apparatus.

EQUIVALENCE OF DIFFERENT RELAYS

In order to reduce the number of designs to a few basic units, we shall first establish the equivalence of basic hydraulic and pneumatic relay or amplifier units.

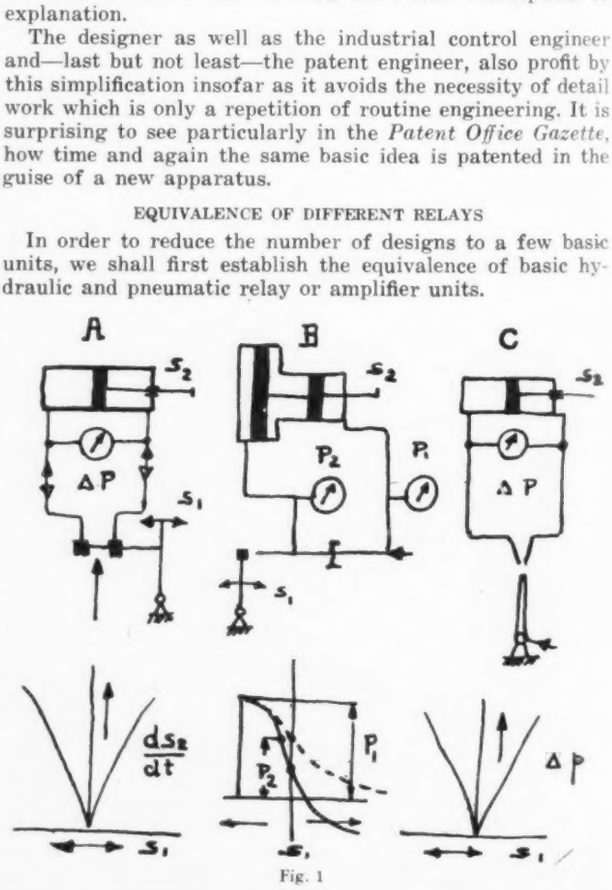


Fig. 1

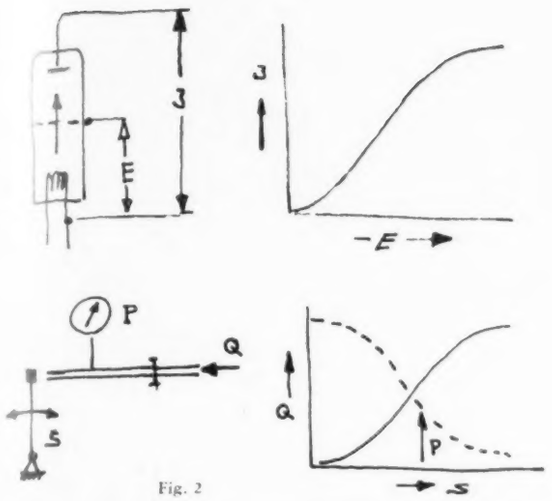


Fig. 2

It is obvious that there are technical advantages in one or the other design—as well as disadvantages, if the reader prefers—but basically these designs are interchangeable.

Fig. 1 shows the three most commonly used relays in the sequence of their historical evolution.

(A) is a typical four-way valve, admitting fluid under pressure to either side of a double-acting piston and thus moving the piston in either direction.

(B) shows an arrangement used in most air-operated and in one hydraulic-relay controller, where two orifices in series, one fixed and one variable in size, vary the pressure of the operating fluid. This modified pressure is then either directly applied to a spring-loaded diaphragm, or, as in the figure, the difference between the supply pressure times one piston area is balanced against the modified pressure times a larger area. Again we obtain a movement of the double piston as a function of the relay displacement.

In the third example, (C), the velocity head of a fluid jet is used to create differential pressures which are in turn applied to operate the double-acting piston as shown. As the author is most familiar with this design, and as it lends itself particularly well to simplifications of diagrams, it will be used as "the relay" in the majority of diagrams in this article—a decision which seems to be justified also by the equivalence of the different systems.

(A), (B) and (C) all have in common that a movement s_1 of the pilot results in creating a pressure difference ΔP (more correctly an energy flow of which ΔP is the result) and a rate of travel of the cylinder which is more or less proportional to the deviation.

In other words, the three relays are energy-control valves responding to the displacement (s) with an energy flow as represented by ds_2/dt. They are in this respect similar to a triode which for a given grid voltage (E) (instead of the parameter s_1) controls a proportional anode current (J) as shown in Fig. 2.

It is, however, important to realize that these three relays are not self-compensating, i.e., that the drawn characteristics depend on the individual relay and vary with pressure, mechanical design, production processes, age, voltage, etc.

We shall see later on how by a trick in design—which may be called a "negative feed-back" or "balancing circuit" —this variability can be eliminated.

Thus we have established the equivalence of the three basic fluid pressure relays.

The next step is to reduce the number of "signals" or variables which affect the relays.

In order to demonstrate the approach to this problem, let us consider a gas thermometer as shown in Fig. 3.

Taking advantage of the definite relation between temperature and saturated vapor pressure, the thermometer produces either:

a) a pressure (P)
b) a movement (S) of the bellows or of the pointer of the pressure gage
c) a force (F) if the bellows movement is restricted.

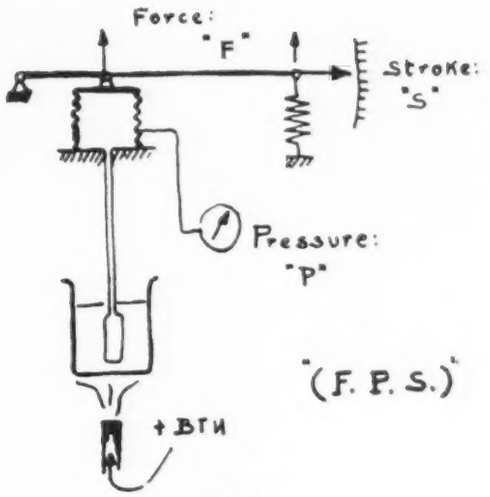


Fig. 3

It seems, therefore, promising to investigate the equivalence of the above three "F.P.S." units, that is—

Force = "F" Pressure = "P" Stroke = "S"

and to find out if they are all interchangeable insofar as each one should be able to represent the others.

It is evident that a further reduction of the number of variables could be obtained by combining "F" and "P." However, as (P) is one of the most common variables in the field of industrial instruments, such an approach would become rather academic.

To prove that each one of the three variables is interchangeable with the others, there will be shown, in discussing the next figures, the nine possible combinations and, in passing, some typical applications will be mentioned.

The diagrams will show one solution each for direct conversion of "F.P.S." units and one with the use of a fluid relay. You will recognize familiar devices as we go along.

Starting with the conversion $P_1 \rightarrow P_2$, i.e., of one pressure into another pressure, Fig. 4, we shall explain the meaning of the negative feed-back mentioned previously.

First, let us consider the simplest mechanical solution. Two pistons of different areas, F_1 and F_2, are connected to each other. Applying a pressure P_1 on F_1 results in a direct proportional pressure P_2. Friction and leakage, however, introduce a hysteresis effect which is not permissible if greater accuracy is demanded.

In such cases, and when great amplification of pressure is demanded, a relay is used. Fig. 4 shows a typical device of this type. You will recognize in it a pressure regulator

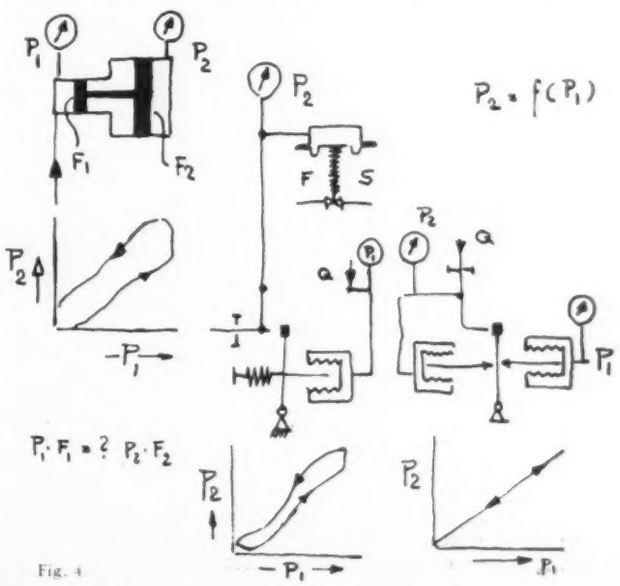


Fig. 4

as sold by a number of manufacturers of automatic controllers. Any variation in P_1 results in a variation in P_2.

Again, however, this relationship is not direct proportionality, but will vary with individual designs and with different instruments.

The perfect solution is the negative feed-back. The pressure (P_2) produced by the relay is used to counteract the bellows action and thus to establish the relation $P_1 \rightarrow P_2$ independently of supply pressure variations or relay characteristics.

Only in these designs can we definitely speak of an equivalence of P_1 and P_2.

The next conversion is the conversion of a force into a pressure. This incidentally leads to a complete program for our following discussion. You will note the nine possible combinations of the three independent variables, i.e.:

$P_1 \rightarrow P_2$	$P_1 \rightarrow F_2$	$P_1 \rightarrow S_2$
$F_1 \rightarrow P_2$	$F_1 \rightarrow F_2$	$F_1 \rightarrow S_2$
$S_1 \rightarrow P_2$	$S_1 \rightarrow F_2$	$S_1 \rightarrow S_2$

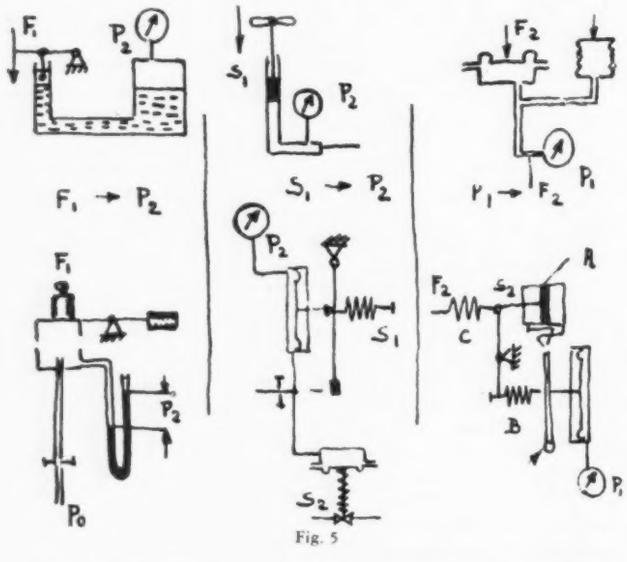


Fig. 5

It is, therefore, necessary to demonstrate the possibility of producing such conversions or translations with the help of relay devices of the type which we discussed before.

In other words, this is the proof of the possibility of converting ($F_1P_1S_1$) into ($F_2P_2S_2$).

Fig. 5 shows, first, a simple solution in the form of a "hydraulic jack."

Next, it shows as an example using a relay a so-called "testing scale" which was developed for calibrating and testing low-pressure controllers and gages. A balance scale beam carries a cup-shaped throttle on one end, which is opposed by a cup nozzle (the secondary variable orifice of two orifices in series). A force applied in the form of a weight increases the pressure in the cup until its product with the area of the cup becomes equal to the weight. Thus a definite pressure (h) is obtained for any applied force (F) and weights can be calibrated to produce definite weights. (Typical ranges: $0.01'' \div 4''$ water column.)

In the next sketch of Fig. 5 we see the interchangeability or conversion of a movement (S) and a pressure (P). First a rather crude device—a piston in a bicycle pump—creates a pressure as a function of the pump stroke $S_1 \rightarrow P_2$.

A relay application of this class is a remote-loading or setting device which is extensively used for positioning of diaphragm-motor valves. The diagram is self-explanatory. A compression of the spring (s_1) produces a definite loading pressure (P_2).

This establishes the interchangeability of

$$P_1 \rightarrow P_2,\ F_1 \rightarrow P_2 \text{ and } S_1 \rightarrow P_2$$

We shall now discuss the conversion of

$$P_1 \rightarrow F_2,\ F_1 \rightarrow F_2 \text{ and } S_1 \rightarrow F_2.$$

The simplest device for converting a pressure into a force is a diaphragm or bellows, or a piston.

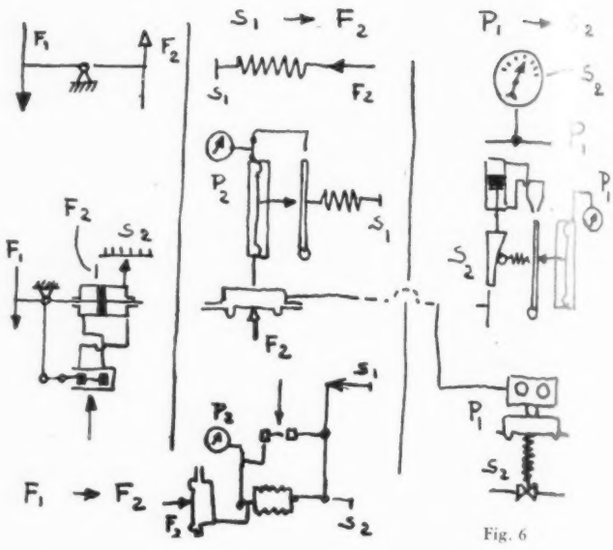


Fig. 6

The conversion with a relay (see the last sketch in Fig. 5) may at first glance look rather complicated. It has been chosen, however, to demonstrate how in many cases the conversion uses intermediate steps. The pressure applied to the jet moves the piston in cylinder (A), counteracting the force of P_1 by compression of the spring (B). S_2 in turn compresses spring (C), thus producing the force F_2.

The solution uses, therefore, the steps $P_1 \rightarrow S_2 \rightarrow F_2$.

The oldest device for converting F_1 into F_2 is the lever or scale shown in the first sketch of Fig. 6. Below it, an automatic scale which utilizes a relay is shown. Note that, strictly speaking, we have a conversion $F_1 \rightarrow S_2 \rightarrow F_2$. An unbalance produced by F_1 produces a displacement of the pilot and this in turn produces a movement of the cylinder until balance is restored.

The conversion of S_1 into F_2 is familiar to us in the mechanism of a compression or tension spring, as in the next sketch. A relay device as shown in the sketch just below uses the same spring, but permits greater amplifications.

In the other sketch the conversion follows the course

$$S_1 \rightarrow P_2 \rightarrow S_2 \rightarrow F_2.$$

Designs of this type are found in turbine governors which start with a governor movement S_1 and position the steam supply valve proportionally to a relay pressure.

There remain only three more possible conversions:

$$P_1 \rightarrow S_2$$
$$F_1 \rightarrow S_2$$
$$S_1 \rightarrow S_2$$

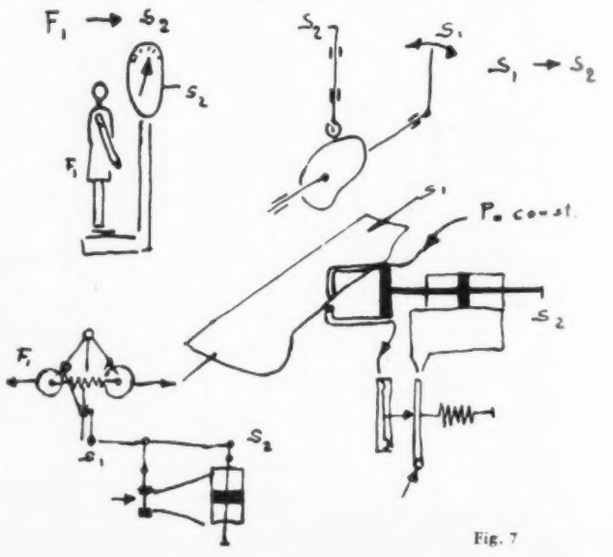


Fig. 7

The simplest device for the conversion of P_1 into S_1 is the pressure gage—be it the U-gage, the Bourdon tube, or the liquid-sealed bell.

The solution using a relay (right-hand sketch of Fig. 6) with cam was introduced to show that it is not necessary that the relationship be of direct proportionality.

Designs of this type are familiar to you in the form of "valve positioners," "valve precisors" or "true stroke regulators," which position a control valve in response to pressures which are applied to a pressure-responsive bellows actuating a relay.

As an example of a force → stroke converter, we first see in Fig. 7 a weighing scale.

In the relay application (next sketch) a speed governor takes a position (S_1) as a function of the speed of the prime mover due to the centrifugal forces F_1. This S_1 is compensated by S_2; the conversion, therefore, is

$$F_1 \rightarrow S_1 \rightarrow S_2.$$

We complete our nine cases by converting $S_1 \rightarrow S_2$.

A cam presents a simple mechanical converter. An interesting mechanism doing the same with power amplification and no wear on the cam is shown in the tool follow-up, on the right-hand side of Fig. 7. Air with reasonably constant pressure is blown across the edge of a template into a receiving nozzle. Variations in pressure in the receiving nozzle are applied to the pressure regulator which moves the nozzles in such a way that the pressure is restored.

We have thus established the possibilities for interchanging all "F.P.S." values.

The choice of individual designs and the use of intermediate steps is the secret of the superiority of one solution over another.

There remains only to add the conversion of the above units into energy flows.

As most electrical variables can be represented either by forces (F) (magnetic or electrostatic attraction), or strokes (S) (instrument indications), it is sufficient to mention the conversion into electrical units as a possibility.

An example is the typical thermoelectric pyrometer potentiometer of the self-balancing type. A potential representing temperature causes a current (energy) to flow and this current in turn creates a magnetic field and finally a force. The force overcoming the action of the biasing galvanometer spring produces a stroke (S_1) of the galvanometer needle which in turn controls a source of electric energy flow and thereby the rotation of a motor (S_2). The motor finally controls the value of the balancing potential which opposes the thermal e.m.f. and reduces the galvanometer current to zero. We therefore find—

Energy → Force → Stroke (S_1) → Energy → Stroke (S_2).

All this seems to be a somewhat roundabout way, but so far it has survived due to the absence of a simpler solution.

We have met the energy factor before, insofar as all control-system relays are energy flow control valves; and

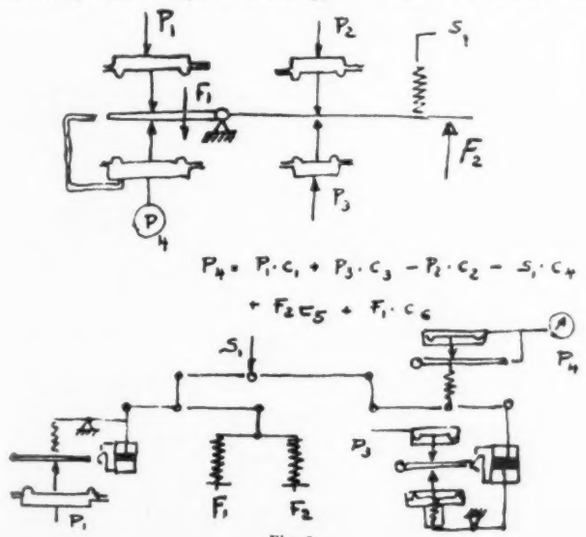


Fig. 8

we shall find the introduction of energy flows helpful in our next steps. Basically, however, we already have all the tools in our hand as energy flows can be measured and thus represented by (P) (differential pressure across restrictions), (F) impact, or (S) using indication of instruments.

TOTALIZING

We have the choice of totalizing
pressures (P)
forces (F)
strokes (S)

Fig. 8 shows two possible solutions.

$$P_4 = P_1\ C_1 + P_3\ C_3 - P_2\ C_2 - S_1\ C_4 + F_2\ C_5 + F_1\ C_6$$

This example gives also the solution for adding or subtracting forces and movements.

It will be noted that forces (F) are used as a common denominator and that finally (F) is converted into P_4.

Below it in Fig. 8, the design using (S) as a common denominator looks somewhat more complicated. Here the totalizing is done by whiffletree arrangements, a solution common in turbine governor designs. For design reasons the pressure (P) as a common denominator is usually impracticable (though not impossible) as pressures cannot be directly summarized. A detour over forces, strokes, or energy flows is usually necessary in such cases.

MULTIPLYING

For multiplication there is, of course, the old standby of the lever, the length of which determines either a stroke or a force. However, there are a number of problems where the introduction of proportional energy flows is advantageous.

For instance, a P or ΔP is given, representing a certain flow rate. If the ΔP is to be multiplied by a different factor to compensate for barometric pressure, density variations,

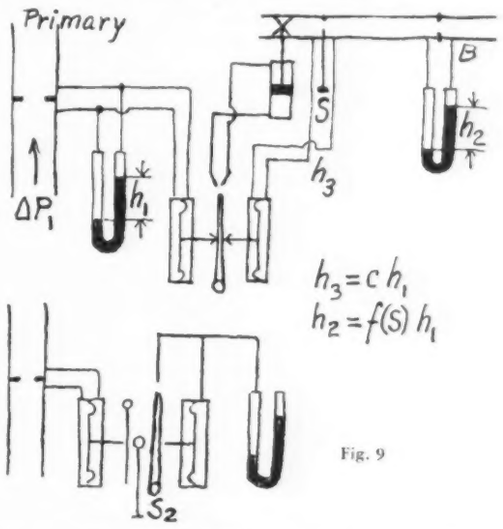


Fig. 9

etc., the best solution would be a variable restriction, thus using a stroke S_2 in order to introduce a factor.

In most cases, however, this is not possible. A solution is then found by establishing a secondary rate of flow which is directly proportional to the primary flow (conversion $P_1 \rightarrow P_2$) and by making the correction on a restriction in the secondary flow as shown in the upper sketch of Fig. 9. The differential pressure obtained across an additional restriction in the secondary flow line is then a function of P_1 and S.

A simpler solution, shown in the lower sketch of Fig. 9, uses a variable mechanical lever system to introduce different factors.

Incidentally, the above scheme shows other possibilities, i.e., getting square-root functions or second-power functions. It also offers summarization of flows by adding the proportional pilot flows and then measuring their sum total. All this is, however, basically only a combination of the above methods.

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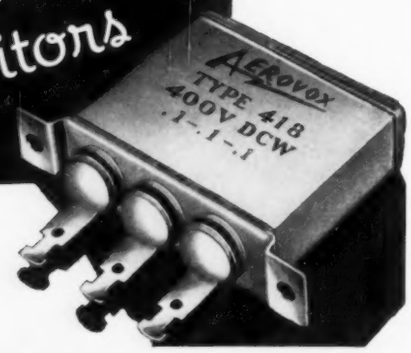

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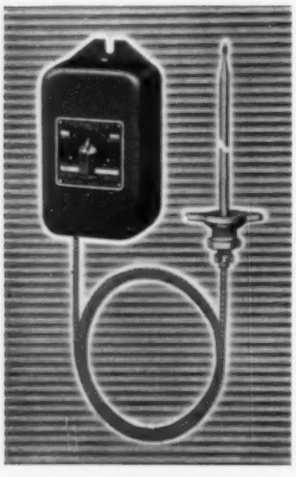

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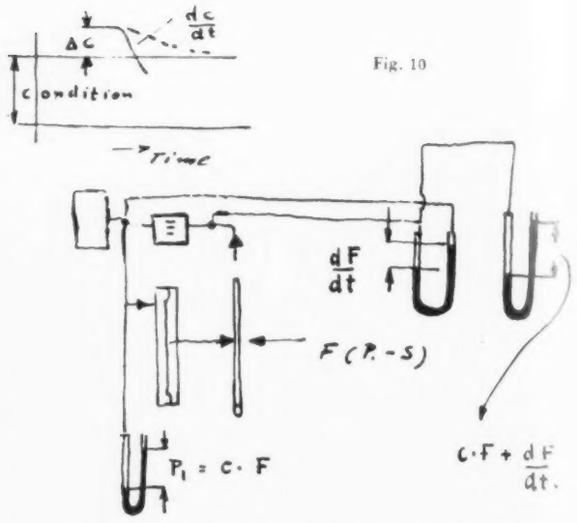


Fig. 10

CONTROLLERS RESPONSIVE TO RATE OF CHANGE

One phase of conversion, however, needs additional comment. It is more and more realized that future automatic-control technology will use the rate of change of the condition to be controlled in addition to the deviation or change of the condition. See Fig. 10.

It becomes, therefore, necessary to find devices measuring the first derivatives of "F.P.S."

(1) One of the simplest devices (eliminating electrical solutions) is a restriction in the pressure line transmitting (P). As (P) is built up by a change in volume and as (P) is proportional to the weight of a gas in a given volume, the rate of flow into a closed space becomes a measurement of "rate of change," if at the same time the pressure in the space is made proportional to the condition. This is shown in the diagram of Fig. 10.

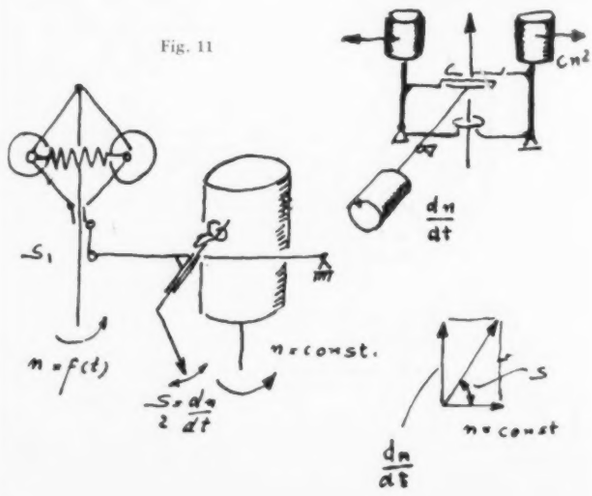
A "(F.P.S.)" change is balanced by a proportional air pressure P_1. However, a restriction is inserted, which measures the rate of flow and to the chamber outside of the diaphragm. Using a capillary restriction, the ΔP developed is directly proportional to dP/dt. Evidently, dF/dt or dS/dt can be obtained by converting the F and S values first into P values. (The same solution is used in rate-of-climb indicators on aircraft.)

(2) A very common device to measure rate of change is a dash pot. It is too well known to justify description. It produces a force roughly proportional to dS/dt or to $(dS/dt)^n$.

Both methods have in common that they are sensitive to viscosity (temperature) changes and that the maintenance of clean restrictions is a major service problem.

(3) A more elegant solution is that shown in Fig. 11 as applied to a speed governor. The angle the roller will take

Fig. 11



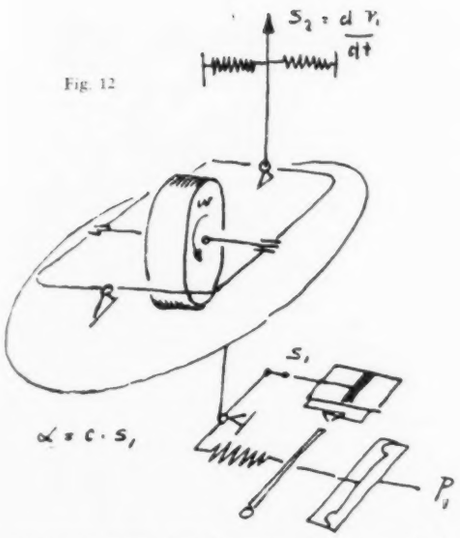


Fig. 12

for any dS/dt is given by the sum of vectors of circumferential speed of the cylinder and ds/dt. This angle s therefore becomes a definite function of dS/dt.

(4) Another solution which has proved successful and may be of interest uses a gyroscope. It is known that a gyro supported in a gimbal ring responds to a displacement of its axis by a force (F) which is directly proportional to $d\alpha/dt$. It is, therefore, only necessary to convert the (F.P.S.) values into directly proportional angular movements (S_1) and one obtains a force (F) which again can be converted into any (F.P.S.) value. Fig. 12 shows the conversion into (S_2).

(5) In conclusion, a method is described which is somewhat unusual A fluid jet nozzle (see Fig. 13) which is stationary relative to a turntable delivers fluid between and into two receiving orifices. As long as the table is stationary the ΔP is zero. As soon as it rotates, however, with the angular speed of $d\alpha/dt = C\,dS/dt$, we obtain a deflection of the fluid jet for two reasons:

(a) the Coriolis acceleration $2mv \cdot d\alpha/dt$ with v the fluid jet velocity gives a ΔP proportional to $d\alpha/dt$ and

(b) the angular acceleration $\xi = d^2\alpha/dt^2$ produces a deflection of the jet familiar to anyone who ever handled a fire or garden hose.

This opens the possibility of obtaining in addition the second derivative.

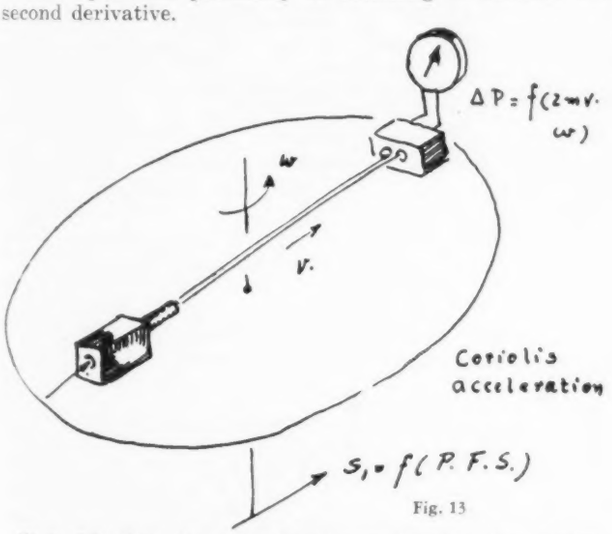


Fig. 13

It is felt that the analysis of second and higher derivatives should be made the subject of a second article.

It is hoped that the foregoing analysis, although admittedly presented in a rather abstract form, will serve as a guide through the multitude of relay solutions and will be of some assistance in classifying and analyzing future designs.

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The Improved Penn State Smokemeter

By P. H. SCHWEITZER
Professor of Engineering Research, The Pennsylvania State College

ORIGINALLY developed in 1938*, the Penn State Smokemeter has been widely adopted since then for measuring the exhaust smoke of Diesel engines and also in a modified form for oil burners.

Its principle of operation is shown in Fig. 1. It consists of a tube of about 1¾" inside diameter, and 18" long, with glass windows at each end. A lamp is mounted at one end and a lightmeter on the other end. The exhaust is admitted in the center through a tubing that connects the smokemeter tube to the exhaust pipe. The smokemeter tube is

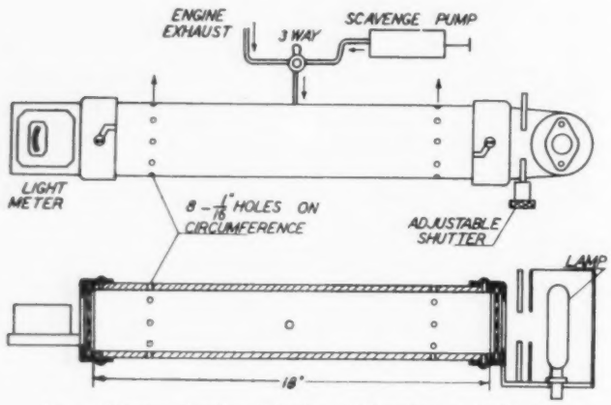

Fig. 1. Diagram Showing Principle of Operation of Smokemeter.

open to the atmosphere through a row of small holes at both ends, 2" from the windows. An adjustable shutter was interposed between the lamp and the window by which the lightmeter reading for clear could be set to a standard value. This is necessary to take care of variations in light intensity and soiled windows.

The smoke density was measured in the following way: The tube was first scavenged with air (shop air was used), and the lightmeter hand was brought to register 50 foot-candles on the General Electric lightmeter, by adjusting the shutter. Then by the 3-way cock the smokemeter was brought in connection with the exhaust, and when the lightmeter reached its new equilibrium in about 30 seconds, the foot-candle reading was recorded. If the reading was, say, 30 foot-candles, the loss in light intensity is $20/50 = 40\%$ and the corresponding smoke density is 40%. If the instrument registered no loss in light intensity when switching from free air to engine exhaust, the smoke density is, of course, zero.

The feature of this smokemeter is that it samples the smoke, instead of measuring the smoke density of the full stream. The smoke fills the smokemeter tube under atmospheric pressure and is almost at rest. Therefore, the smoke determination does not depend on the exhaust gas velocity or quantity. It does not depend on the light source intensity, lightmeter sensitivity and window deposits, as these factors are neutralized by the shutter adjustment. The only factor that enters is the length of the smokemeter tube, for which a standard length of 18" was proposed. If the lightmeter hand goes back from 50 to X, then the smoke density is $100\ (1 - X/50)$ percent.

Since its adoption, considerable work has been done on this smokemeter by engine and oil company laboratories with a view of improving its accuracy and convenience. These improvements will be briefly described.

RHEOSTAT

As a means of adjusting the incident light intensity, the shutter was replaced by a rheostat. It was first argued that a rheostat which reduces the current voltage not only reduces the intensity of the light, but changes the color. The photocell may be more sensitive to one portion of the spectrum than to others. In this way an error might be introduced in smoke testing.

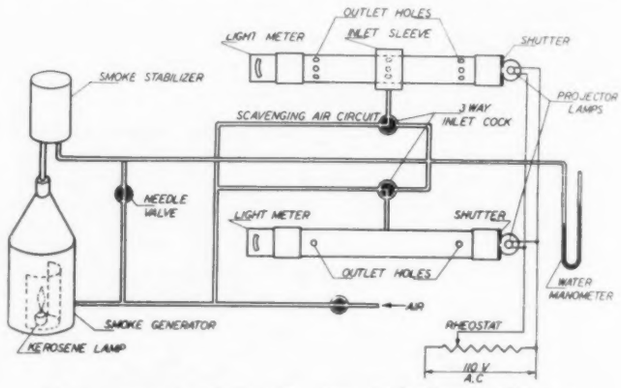

Fig. 3. Set-up for Comparative Tests of Smokemeter Tubes to Determine the Effect of the Number and Size of Inlet and Outlet Holes With and Without an Inlet Sleeve.

The point was decided by comparative tests in our laboratory. Smoke was simulated by layers of tracing paper, and the soiling of the windows by additional layers of tracing paper. The "percent smoke" was then determined with clear and soiled windows by both the shutter and rheostat arrangement. The result of the test shown on Table I was that the rheostat is fully equivalent to the shutter and its operation more convenient.

TABLE I

		Clean Window	
	"Percent Smoke" of	*Shutter*	*Rheostat*
	0 layer	0	0
	1 layer	41	44
	2 layers	69.1	69.3
	3 layers	84	82
	Slightly Soiled Window (1 layer)		
	0 layer	0	0
Additional	1 layer	44	44
	2 layers	70	70
	3 layers	84	83.1
	Much Soiled Window (2 layers)		
	0 layer	0	0
Additional	1 layer	44	44
	2 layers	71	70
	3 layers	85	83.5

*P. H. Schweitzer, Smokemeter of Simple Design Tests Diesel Combustion, *Automotive Industries*, August 20, 1938, page 238.

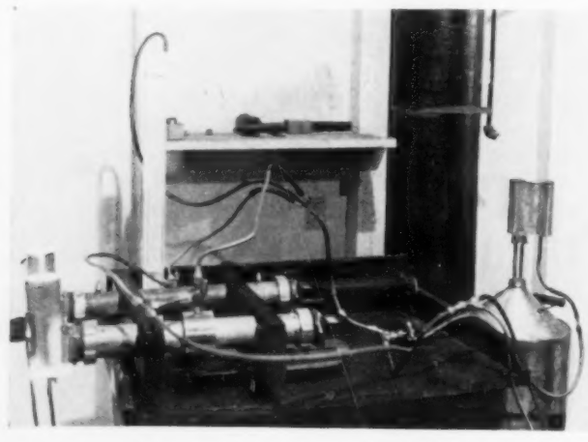

Fig. 2. Setup of Smokemeters in Parallel.

SLEEVES AND HOLES

In the Penn State smokemeter the exhaust gases enter through one hole in the center and exit through holes at each end of the smokemeter pipe. Sleeves have been proposed around the inlet and exit holes to distribute the smoke. Since a more homogeneous distribution of smoke affecting the lightmeter readings could be claimed, comparative tests were undertaken with a smokemeter tube having sleeves and one without sleeves. The number and size of inlet and exit holes were also varied. The report on these tests is as follows:

Two complete smokemeters were tested, their smoke and light circuits being put in parallel and readings were taken simultaneously. The setup is shown in the photograph, Fig. 2, and the scheme in Fig. 3.

As it was not convenient to operate on an engine, the smoke was generated by a small kerosene lamp burning in a closed tank. The air was supplied under a small pressure and the heavy smoke, after going through a stabilizing tank and being mixed with compressed air in a proportion which could be varied by opening more or less a needle valve, was conducted into both smokemeters. A water manometer gave approximately the pressure of the entering smoke (0.1" to 1" water). The readings were fairly steady

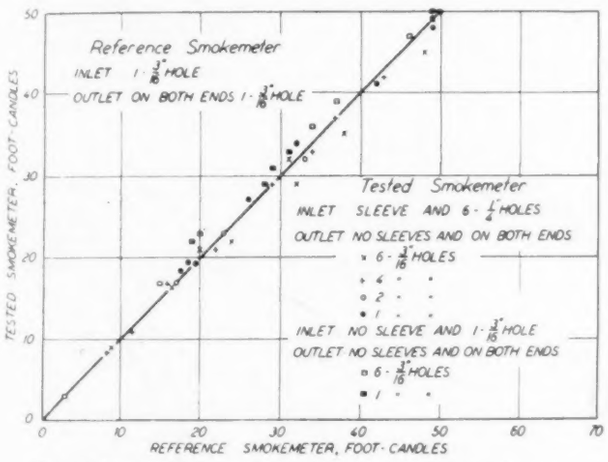

Fig. 4. Comparative Tests of Different Inlet and Outlet Arrangements with the Penn State Smokemeter.

and different densities of smoke easily obtained. The results (Fig. 4) show that the smokemeter reading is practically the same with and without sleeves and is not affected by the number and size of openings within the investigated ranges. The range covered from six holes, ¼" diameter to one hole, 3/16" diameter for the inlet and from 2 times six holes, 3/16" diameter to 2 times one hole, 3/16" diameter for the outlet.

The most convincing test was, when five out of six outlet holes on each end of the smokemeter tube were first shut by a strip of tape, then the tape was removed and the lightmeter reading did not change. The spreading of the points on the curve, Fig. 4, is probably due to experimental errors. The smokemeter without sleeves gave the correct reading in a shorter time than the one with an inlet sleeve; that is possibly due to the additional volume inside the sleeve.

MICROAMMETER

While some photoelectric lightmeters read in foot-candles, others give the readings in microamperes. What calibration is most suitable for smoke measurement?

The current generated by a photo-sensitive cell is a function of the light intensity and the area of the light-sensitive surface.

$$C = f\ (\int ida).$$

If the intensity of the incident light is uniform and the total exposed surface is A

$$C = A\ f\ (i).$$

Generally C is not proportional to i. The foot-candle meter is supposed to give readings that are proportional to i, while the microammeter readings are proportional to C.

Setting a smokemeter with a Weston microammeter in parallel with a smokemeter with a General Electric foot-candle meter and making simultaneous readings gave the curve, Fig. 5, showing the reduction in microamperes.

Which reading is preferable for a smokemeter scale? The smoke particles obstruct the light and their effect is the same as if part of the light source, or photocell, were

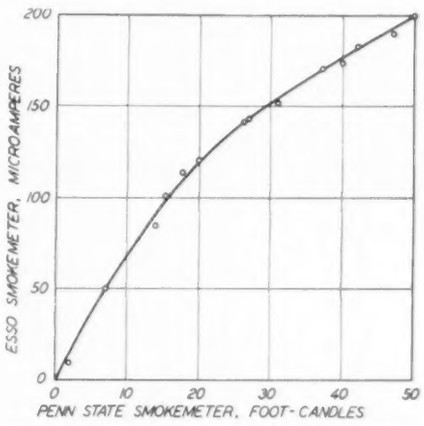

Fig. 5. Comparative Readings on Penn State and Esso Smokemeters.

screened off. Therefore, it seems logical to use as smoke scale the relative area, the obstruction of which causes an identical change in the photocell current. Since foot-candles vary in direct proportion to the shielded portion of the photocell while micramps do not, foot-candles appear to be a more logical scale for smoke density than microamps.

It seems advisable, therefore, to replace the dial of the microammeter with one which is proportional to the foot candles of the light incident on the photo cell. The curve, Fig. 5, could be used for that purpose if one would be sure

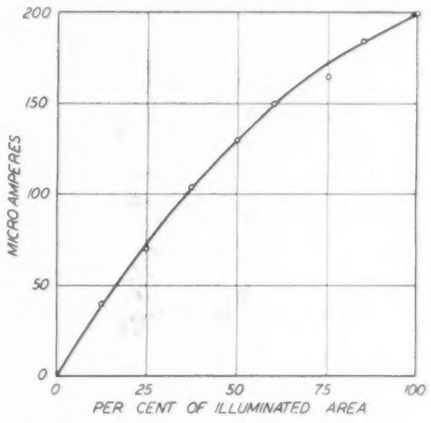

Fig. 6. Calibration Curve of the Esso Lightmeter.

that the General Electric foot-candle meter is accurate. There is reason to believe that it is not.

A better calibration can be obtained by screening off 10, 20, 30, 40, 50, 60, 70, 80, and 90 percent of the photocell surface and recording the corresponding microamp readings.

The intensity of an electric light was found to be uneven throughout the photocell area. Therefore, the readings were made in daylight with screens covering ⅛, ¼, ⅜, ½, ⅝, ¾, and ⅞ of the sensitive area. The results are shown in Fig. 6.

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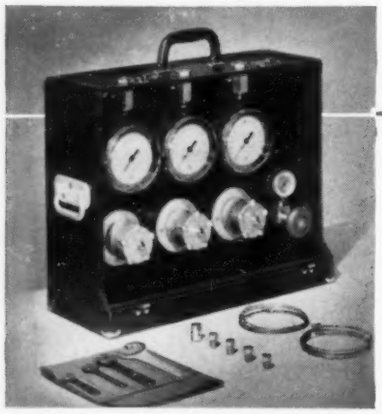

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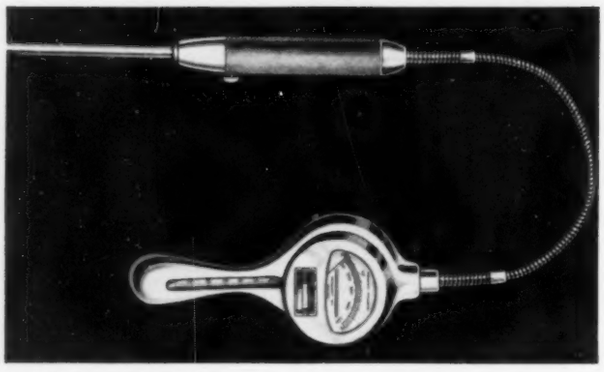

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Fig. 7 is a cross plot of curves, Figs. 5 and 6. If the General Electric lightmeter used were accurate, the cross plot would be a straight line. The actual curve represents the calibration curve of the General Electric lightmeter used in our tests.

The method described could be used to calibrate any microammeter for direct smoke-density readings.

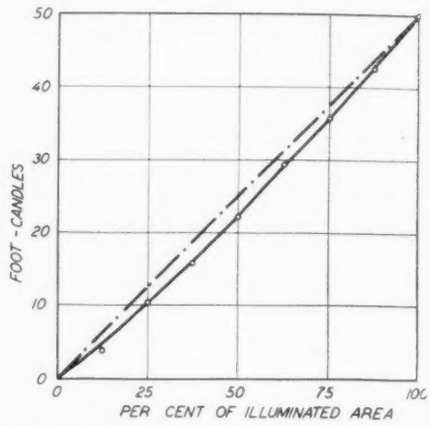


Fig. 7. Calibration Curve of the Penn State Lightmeter (Cross Plot from Fig. 5 and 6).

The photocell is exposed to uniformly dispersed light for which daylight is suitable. The rheostat is adjusted to read full scale (200 microamp). Then 10% of the sensitive area is covered, which causes a reduction of the hand deflection. This point is marked "10". The point corresponding to 20% reduction of the light impinged area is marked "20", etc.

The light intensity of an electric bulb is sensitive to the applied voltage. A 3.9% reduction in applied voltage gave 11.9% variation in lightmeter current and 15% variation in light intensity. Since 5% variation in line voltage is not unusual, ordinary a-c. current should not be used for meter calibration.

EFFECT OF SMOKEMETER LENGTH AND LOCATION

Engine exhaust smoke was determined by three smokemeter tube lengths, 18″, 12″, and 8″, and two locations for

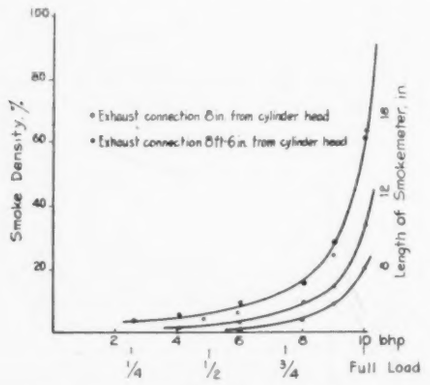


Fig. 8. Effect of Smokemeter Length and Exhaust Connection on Readings.

the connecting tube, 8″ and 102″ from the cylinder head. The results are shown in Fig. 8. It is evident that the smoke density reading is lower with a shorter smokemeter tube, but the location of the exhaust connection has no appreciable effect.

OTHER IMPROVEMENTS

Our first smokemeter was provided with detachable windows for convenient removal of smoke and fog deposits. The Naval Experiment Station of Annapolis mounted a heater coil on the window next to the light meter to prevent water

condensation on it. On the light source end the lamp is sufficient to keep the window free of moisture.

To further facilitate the cleaning of the windows the Esso Laboratory devised the hinged tilting windows shown in Fig. 9. At the same time it replaced the high-wattage projection lamp with an automobile headlight type lamp with reflector. The advantage of this light source is that it is much cooler than the 200-watt projection lamp used previously, and so avoids overheating. The automobile type lamp can be operated either with 6-volt batteries or with 110-volt a.c. through step-down transformer.

IMPROVED SMOKEMETER

A recent model smokemeter that incorporates the described improvements is shown in Figs. 9 and 10. The controls and the indicator are housed in one box while the smokemeter tube is separate with provisions to fasten it on

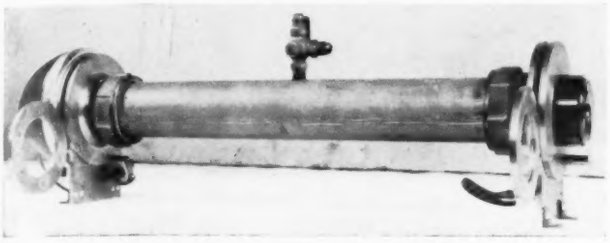


Fig. 9. Improved Penn State Smokemeter. (Control box separate.)

Fig. 10. Control Box of Penn State Smokemeter. (Note dial calibration from 100 to 0, to read percent smoke density directly.)

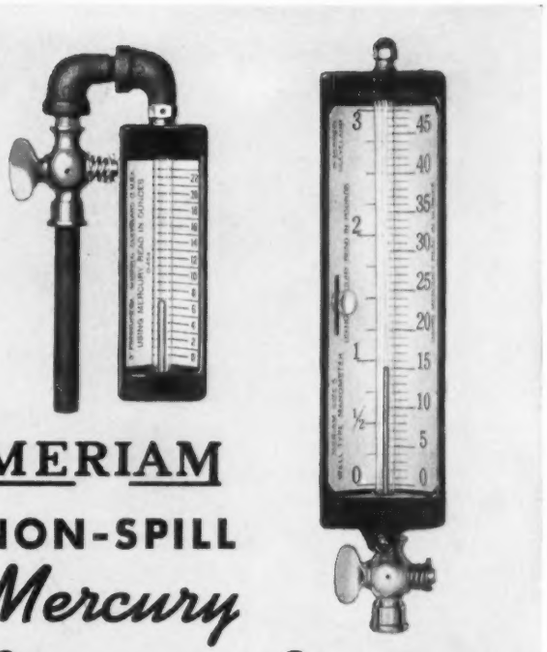
the exhaust pipe or other convenient location. The control box connects with the smokemeter tube through a five-wire cable, for the photocell, the lamp and the heater. The heater coil is mounted inside of the window frame so that it does not obstruct its tilting for cleaning. The heater coil is formed of 20″ of 2.6 ohm/ft. nichrome wire and no adjusting rheostat is necessary.

One intake hole of 5/16″ standard pipe thread and on each end six outlet holes of 5/16″ diameter are used without sleeves. The advantage of the small outlet holes is that only an imperceptible amount of exhaust smoke contaminates the air of the laboratory.

The use of small inlet and outlet holes becomes objectionable if the pressure of the exhaust gas is too low to fill up the smokemeter tube quickly. This will happen if the bleeding point in the exhaust pipe is too close to the outlet into the atmosphere or if the connecting tube between the exhaust pipe and smokemeter tube is too long. The same thing happens in such installations where the exhaust pipe is evacuated by a vacuum pump. In either of these cases it is advisable to employ a vacuum pump to suck the gas sample through the smokemeter.

The connection to the engine exhaust pipe is of 5/16″ copper tube if the length of the line does not exceed 3 feet. If the line is 3 to 8 feet, ⅜″ copper tube should be used.

The dial of the microammeter is calibrated to read directly "percent smoke" from 100 to 0.



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These gauges measure up to 48 oz. They are 9½″ high, 2″ wide, 1¾″ deep and weigh 1 lb. 8 oz. The scales are graduated on the left of the tube to read from 0 to 3 lbs. by ¼ lb. increments, and are graduated on the right of the tube from 0 to 48 oz. by 1 oz. increments. Other scale graduations available.

Housings of the gauges are of cast semi-steel, accurately machined to insure leak-proof fitting of all the component parts. The housing, finished in dull black baked enamel, protects on three sides the heavy walled Pyrex, centrally located tube. Write for Bulletin 3 containing full details.

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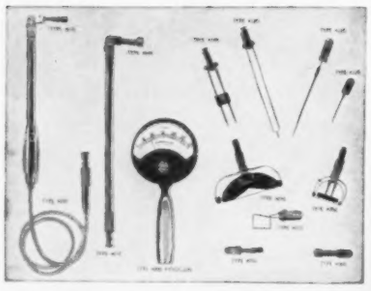

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DIESEL SMOKE

There is no more dependable indicator of the quality of combustion in a Diesel engine than the exhaust smoke. A clear exhaust is evidence of clean combustion, while a dark exhaust is proof of imperfect combustion. When the exhaust is smoky, high fuel consumption and troubles from soot deposits can be predicted with practical certainty. However, exhaust observations are usually made with the free eye, which gives inaccurate results during day time and practically none at night. The exhaust smoke can be judged best with a background of blue sky, but even then the quantity of the exhaust, the observation distance, and the personal element prevent a strict comparison of the observations. On a cloudy day, or in the absence of the sky background, visual observations are less trustworthy, and at night impossible. Hence the demand for an instrument for smoke measurements.

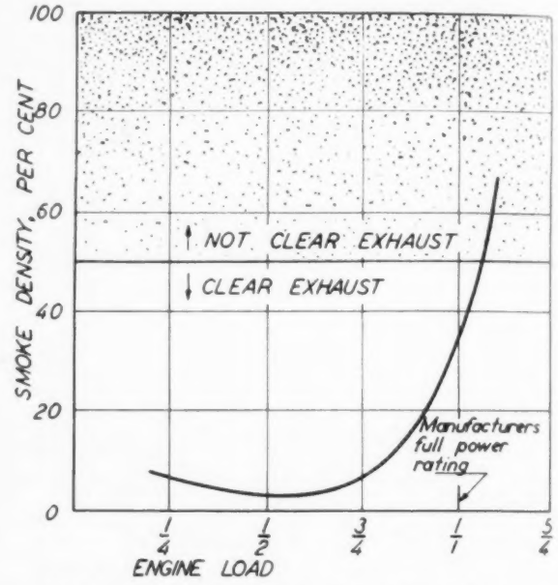


Fig. 11. Smoke Indicator Readings Plotted Against Load.

Fig. 11 shows a typical smoke-density record of an engine obtained by a Penn State smokemeter. It will be noted that between ¼ and ¾ load, the smoke density is practically zero. Beyond the ¾-load point the smoke density increases slowly, while beyond the normal full load it increases rapidly. Against blue sky background the smoke of a small Diesel engine just begins to be clearly visible when the smokemeter registers a smoke density of 50%. When the smoke begins to be a nuisance the Penn State smokemeter reads about 75%.

This suggests other than laboratory uses for the smokemeter. The control of Diesel exhaust smoke on the highways and city streets is being studied by several highway, state and municipal authorities. Any regulation, to be enforceable, requires an objective determination of the violation. The Diesel exhaust smokemeter will probably find its way into the hand of the police.

Manufacturers' rating of a Diesel engine is frequently based on the maximum horsepower the engine is capable of delivering with clear exhaust. Clear exhaust, however, is debatable if based on visual observation of the exhaust smoke, while 50% smoke density (determined by an 18″ long smokemeter) is definite.

ANSWER TO BRAIN TWISTER

Vise, 27 lbs.; clamp, 9 lbs.; hammer, 3 lbs.; wrench, 1 lb. For twenty-five of the forty even-pound amounts, it is necessary to put one or more of these four items in the *same* pan as the unknown. Example, to balance a 14-lb. weight, the 27-lb. vise is placed in the opposite pan and all three other items (9 + 3 + 1) in the same pan.

Arthur H. Thomas
1873-1942

ARTHUR H. THOMAS, founder and president of the Philadelpia laboratory supply firm that bears his name, died on August 31.

With his passing, there vanishes from science, engineering, industry, education and other fields a great personality—universally beloved by all those who knew him. It would seem that as the name of his company became more and more widely known in more and more fields, so did his own person fade into relative obscurity as far as the public was concerned. This was the result of a deliberate policy of self-effacement on the part of Mr. Thomas—a policy which guided his associates as well, so that his death has received but a small amount of notice until now.

And yet, in all the history of instruments and apparatus, there has to date been only one such man. It behooves *Instruments* to signalize his passing in a fitting way—because many people, both inside and outside the Thomas organization, will later appreciate the fitness of permanently recording a few words about this leader in a magazine that serves some of the many thousands of workers whom he served so well during his lifetime.

Arthur H. Thomas was born in Beaver County, Pennsylvania, in 1873; and attended the West-town Boarding School. He first became interested in scientific instruments and apparatus when he became associated with the old Philadelphia firm of James W. Queen & Co. in 1892. In those days—half a century ago—Queen & Co. was the leading optical and scientific instrument firm in the United States. They were not only importers and dealers but were extensive manufacturers of everything from laboratory thermometers to microscopes and from drafting instruments to theodolites. That firm had a romantic history. During the Civil War, officers of the Union Army Engineering Corps used to come to Philadelphia with twenty-dollar gold pieces in their pockets to buy engineering instruments from Queen & Co. and carry them back to the theater of operations.

After the death of Mr. Queen, the decline of that business began. And so, in December 1900, at the age of twenty-seven, Mr. Thomas left Queen & Co. and started his own business, the Arthur H. Thomas Company. He built up a business which became well-known and thoroughly respected all over the scientific world. In fact, when international commerce has not been interrupted by war, the Arthur H. Thomas Company has regularly done business all over the world.

The first of the great Thomas catalogs was issued in 1914. Immediately upon its appearance it was hailed by the American Association for the Advancement of Science as an outstanding contribution to that Association's interests and activities. Every succeeding Thomas catalog was more monumental in its character than its precursor. For many years Mr. Thomas personally wrote the manuscript for these catalogs, which were virtually encyclopaedic reference books in the fields in which the Thomas Company is active: chemistry, metallurgy, biology, biochemistry, pathology, and so forth.

The Thomas Company was among the first, if not actually the first, to realize the importance of standardization in these fields. In their early days they did some manufacturing, but discontinued it to become one of the leading merchandizing houses in their fields. Their success was largely due to Mr. Thomas's insistence on certain things: First of all, every one of the twenty thousand items that they handled had to be the best that was available. Secondly, it had to be standardized as thoroughly as possible or practicable. (He did not ask the impossible, but he did ask the best possible.) Thirdly, the Thomas Company probably was the first house in its field that would send blue-prints and specifications with purchase orders to the manufacturers of *every* piece of equipment they bought. The first dimensional blue-prints and specifications of laboratory thermometers that accompanied the purchase order of a laboratory supply house were used by the Thomas Company, with instructions that to get over their inspection benches the instruments had be made that way. Fourthly, every piece of merchandise that went into the warehouse had to pass skilled inspectors to make sure that it conformed to their standards.

In the matter of inspection, for instance, they probably were the first house in the field who examined every piece of glass apparatus or glass instrument-making, even to an ordinary hydrometer, optically for strain or lack of proper annealing or heat treatment, before it went into their stock bins. If a test tube showed too much strain under a strain-finder, it did not go into their stock.

The attitude of the Company's officer in charge of purchases can be described by a typical interview with a salesman. The interview would be essentially as follows: "Can you make them this way? How much more will it cost? Will it be any better?"

If the answer was, "Yes, we can make them that way; they will cost more, but they will be better," the invariable reply was, "Go ahead and make them that way, and we will pay more for them."

Mr. Thomas was deeply interested in education and at the time of his death was a trustee and director of Bryn Mawr College and a member of the Board of Managers of Haverford College. He was also a member of the Board of the Provident Mutual Life Insurance Company.

Arthur Thomas was an intensely human man in addition to being a man of really gigantic intellectual capacity. Everybody who knew him not only respected him and admired him but loved him; and the people in his organization are completely grief-stricken.

Ordnance Production Gaging

By CAPTAIN RUSH A. BOWMAN

In charge of Pittsburgh Gage Laboratory, Ordnance Department, U. S. Army

CHAPTER IV

OFFSET DIMENSIONS

Four types of gages are used for gaging offset dimensions: flush pin, plate, gooseneck, and indicating. However, none of these four types is identified solely with the determination of offset dimensions. Plate and indicating types are used for all classes of measurements and determinations. The flush pin type is used widely for determinations of position and alignment. These types will, of course, be discussed here only as they apply in inspection of offset dimensions.

Flush Pin Gages

A flush pin gage normally consists of two main parts, a body and a movable pin. The body will normally contact one surface. The pin then moves until it contacts the other surface and the distance between the surfaces is determined by the relative position of the pin in the body. The name is derived from the fact that the pin will usually extend through the body (see Fig. 1), and be ground flat on the side opposite the surfaces contacting the part to be gaged. At the point where it protrudes, there usually will be a boss on the body which is ground in such a manner that when the distance between the surfaces being gaged is at one limit of the tolerance, the end of the pin will be flush with one semicircular surface of the boss; and when the distance is at the other limit of tolerance, the pin will be flush with the other semicircular surface.

A flush pin gage is an accurate instrument. When flush surfaces are ground and lapped properly, the edges sharp, and there is no play between body and pin, an experienced inspector can determine an error of 0.001″ by the "feel" of the pin. The end of the pin should, of course, stand between the two "steps" or semicircular surfaces; and the fingernail is used to reveal deviations. This type of gage has almost no limit as far as size of tolerance goes. It is as accurate when component tolerance is 0.005″ as when tolerance is 0.500″ and can be used for tolerance as low as 0.001″ if the inspector is skilled.

These gages further command wide usage because of their adaptability to difficult gaging problems. Consider the difficulty which might be experienced in even the direct measurement of, for instance, the depth of a hole 0.020″ in diameter and 0.500″ deep. The use of a flush pin gage makes this inspection simple.

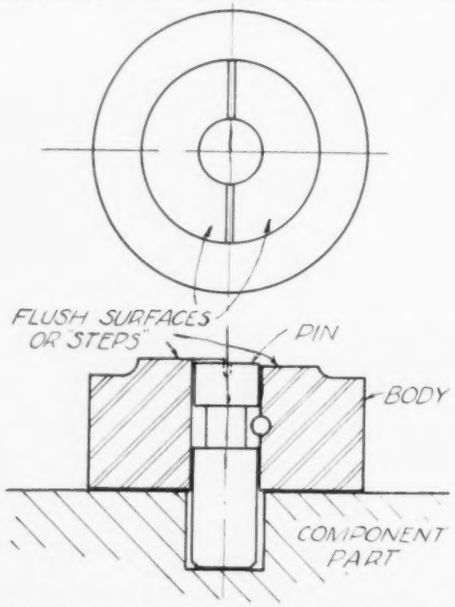


Fig. 1. A flush pin gage shown gaging the depth of a hole. In the position shown, the top of the pin stands between the two "steps" on the body when the bottom touches the bottom of the hole. The part, therefore, is within tolerance.

Servicing of flush pin gages is comparatively simple. Notice that there is no wear allowance specified in the design. There will be a certain amount of wear. This wear will occur on the gaging surfaces while the "step" will remain the same and consequently the tolerance will remain the same but the basic dimension of the component part will not be shown correctly. Servicing is accomplished by setting the pin in such a manner that basic size exists between gaging surfaces and grinding the pin and one flush surface together and grinding the other flush surface to the correct tolerance. Contact surfaces on end of body and pin must be true before steps are ground.

As a rule, flush pin gages can be ruggedly constructed; designed for a maximum of life, a minimum of servicing. Their most vulnerable spot is the bearing of the flush pin within the body. The surfaces are fit surfaces and the size of the hole in the body and the diameter of the pin are specified normally only in nominal dimensions. The pin must be "lapped in" to the body. The fit should be a snug sliding fit because if it is loose or "sloppy," dirt and metal chips will find their way into the bearing and cause either seizure or excessive wear. In the former case, difficulty will be experienced in its use. In the latter case, accurate readings cannot be taken.

Cases frequently occur where a flush pin measuring the depth of a counter-bore or the depth of a drilled hole will contact a seat for the pin, which is either extremely small or has a tapered surface. In cases of this kind, the diameter of the pin entering the hole should be held as close to the minimum diameter of the hole as possible.

Compound* Flush Pin Gages

Many cases arise where it is possible by the use of compound flush pin gages to gage more than one offset dimension at a time. Flush pin gages provide the exception to the rule that more than one "not go" condition can be gaged with one gage.

In a typical case, such as a socket for a thrust bearing (see Fig. 2) one surface will be used as a master surface. In this case it may be surface *A*, *B*, or *C*. The portion of the flush pin gage contacting this surface will in all cases on the "feeling" side be the surface without a "step." Deviations from basic distances will exist in reference to this surface. In case *A*, *A*1 is the master surface, *A*2 and *A*3 each have "steps." In case *B*, *B*2 is the mastering surface and *B*1 and *B*3 have "steps," and in case *C*, *C*3 is mastering and *C*1 and *C*2 have "steps." This provides identification from the gage of the mastering surface and the point from which other dimensions are taken.

Compound flush pin gages have essentially the same advantages and disadvantages of ordinary flush pin gages except, of course, that it is possible to gage two surfaces with one gage inspecting for both maximum and minimum limits.

Plate Gages

Plate gages may be used for inspection of either heights or depths which are essentially offset dimensions. Their use is simple but in all cases is dependent on "feel." This type of gage provides more rapid inspection than a flush pin gage but it requires more accuracy in its use. This type of gage is in general a more simple type to manufacture.

The gage shown in Fig. 3 is used by pressing surface *A* firmly to the surface of the component part and advancing

*The use of "compound" is not standard Army nomenclature.

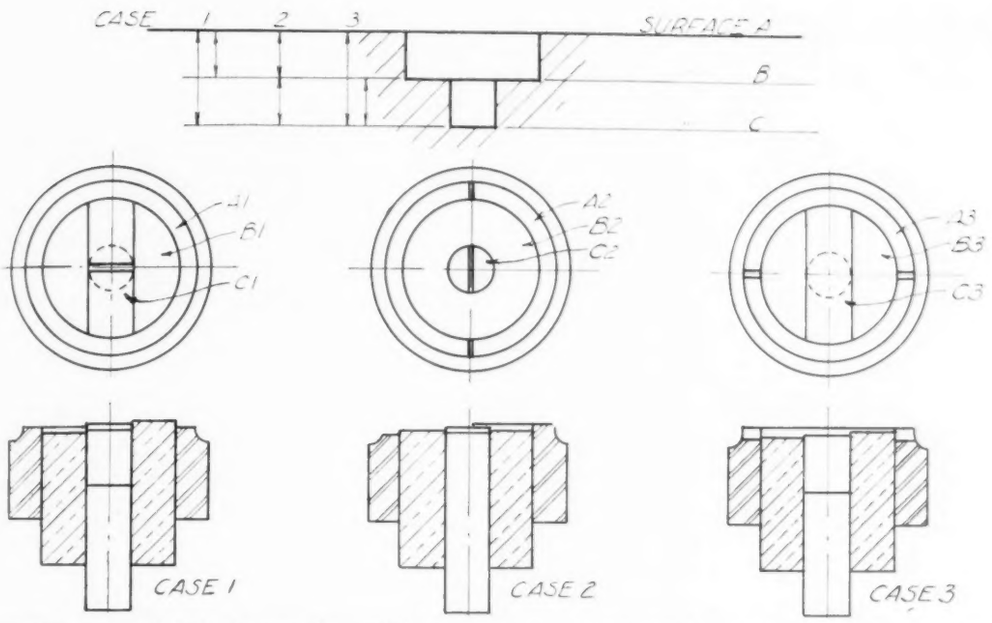


Fig. 2. Below are three compound flush pin gages all intended for the inspection of the thrust bearing socket shown above. The type which applies will depend upon which surface on the part is the master surface. Stay pins, as shown in Fig. 1 for holding flush pins in place, are here omitted for the sake of simplicity.

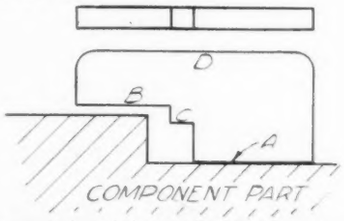


Fig. 3. A plate gage is here being applied in inspection of the shoulder shown. "A" rests on the surface of the part and as the gage is pushed on this surface toward the shoulder "B," the "go" size should pass over. The "not go" surface "C" should not pass over the shoulder. The surface "D" has no part in component inspection. It is discussed under Inspection of Plate Gages.

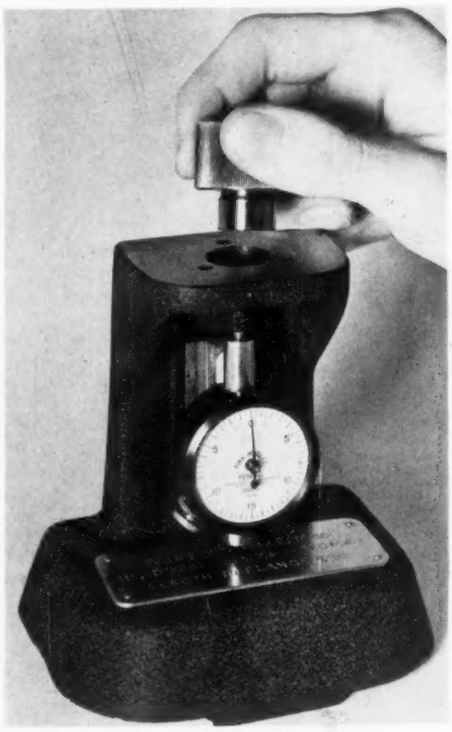


Fig. 4. An indicator type gage is here being used to gage distance between end of pin and shoulder. When inserted in gage as shown, this length will register on dial.

towards the shoulder. When the gage is used in this manner, the shoulder should pass under surface *B* and not under surface *C*.

Indicating Type Gages

Indicating type gages are frequently used in the measurement of offset dimensions. In general, they perform the same sort of duty as a flush pin gage with the exception that, in this case, the indicator is the movable part instead of the pin. An example of such a gage is shown in Fig. 4. This type of gage, of course, has all the limitations and advantages of any ordinary indicator gage—speed, elimination of wear, need for mastering, etc.

Gooseneck Gages

Gooseneck type gages are a frequently used item in Ordnance manufacture. The advisability of placing them in the catagory with offset dimensions may be somewhat questionable, inasmuch as they normally check a thickness. See Fig. 5. However, since the conditions requiring a gooseneck gage are not a normal thickness measure and flush pins are frequently used, these gages are classified in this manner. Gooseneck gages present considerable design problems because of the support of the members. The cantilever effect will produce a certain amount of strain, and this distortion must be taken into effect in gage design. Such gages must not be designed to check to too great an accuracy. A greater accuracy can, of course, be expected from gooseneck gages with a flush pin type head. It should be noted from the construction that the bearing surfaces are an inherent feature when a flush pin type head is used and consequently are quite vulnerable both because of ordinary wear and also dirt and foreign matter introduced in the bearing surface.

Combination Gages

The measurement of offset dimensions frequently lends itself readily to incorporation in a gage of some other type. This is especially true in the measurement of depths of holes and also where the depth tolerance is comparatively large. For instance, lock nuts are frequently employed on "go" thread plug gages and set at minimum heights. In this manner, the "go" gage can be introduced into a component

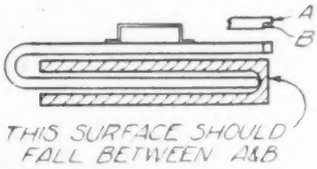


Fig. 5. A goose-neck gage is here employed in inspection of the base thickness of this cylinder. If difficulty is experienced in determination of acceptability of thickness, a straight edge may be placed against surface "A" or "B." Note handle on gage.

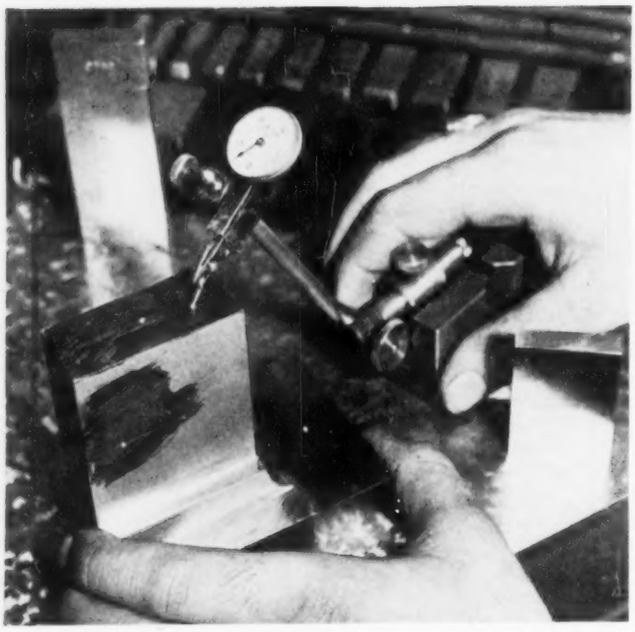


Fig. 6. Use of a dial indicator. A typical use of a dial indicator is here shown in comparing the height of a machined part with gage blocks set up in upper left hand corner. (U. S. Army photograph.)

part until the lock nuts butt against the top of the hole showing minimum depth of the thread. The depth of a plain hole is frequently gaged by cutting notches in a plain plug gage or scribing lines on the surface of the plain plug gage at the points which indicate the maximum and minimum depth of the plain hole. In case the notch method is used, the gage is inserted into the hole and a straight edge over the top of the hole should pass over one notch and not over the other, indicating that the depth of the hole is within component tolerance. Many other expedients of this sort suggest themselves. None needs illustration here.

Inspection

Inspection of all types of gages for offset dimensions is most usually done on a surface plate and in general it may be said that the procedure consists primarily of the establishing of the difference in dimensions representing the distance to be measured. This difference is usually established with gage blocks.

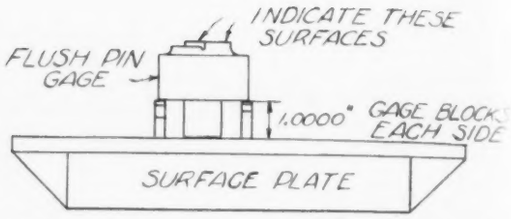


Fig. 8. Surface plate set-up for inspection of flush pin gage is here shown. All surfaces should be clean; and pin must be resting solidly against surface plate. Indicator as shown in Fig. 6 should be used. Make repeated readings and be sure indicator needle continues to repeat readings.

Flush Pin Gages

If possible, flush pin gages should be inspected from a functional standpoint, that is, under conditions approximating their actual use. For instance, let us suppose that the component part to be measured has a hole $1.000 + 0.005$ deep. Let us further suppose that the gage used to measure this is a simple flush pin as shown in Fig. 1. From the chart of Gagemakers Tolerance, Flush Pin and Adjustable Snap Gages, it is noted that the minimum step would have a dimension $1.0000 + 0.0002$ and the maximum step a dimension $1.0050 - 0.0002$. Two sets of gage blocks, each totaling 1.0000, would be placed under the body of the flush gage in such a manner that the pin could move down and touch the surface plate. Care should be taken that all contacting surfaces—surface plate, gage blocks, pin and body—be clean and free from dirt. If the gage is correct, the pin will be flush with the highest semicircular surface of the body.

This procedure simulates the gage in actual use. See Figs. 6, 7 and 8.

An indicator attached to a surface or height gage is then adjusted until the indicator touching the flush surface of the body shows a reading indicating that a slight pressure is being exerted against the indicator point. As the indicator is drawn across this surface and contacts the end of the pin, there should be no movement of the indicator—or no more movement than the gage tolerance, and in the proper direction, in this case lower.

If a particularly accurate reading is needed, the indicator should not be trusted for more than a few ten-thousandths. If more than this is apparent, gage blocks should be set up to compare readings to determine actual deviations.

Gage blocks are then set up to the dimension 1.0050 and the above procedure repeated.

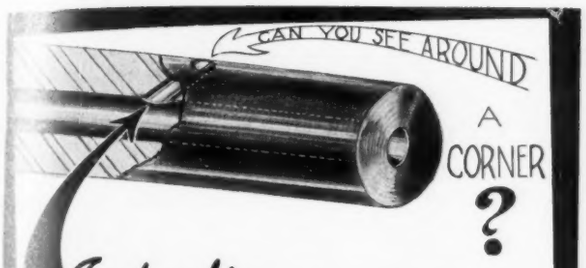
Another method sometimes used is the direct measurement of the parts of the gage. This entails disassembling of

Fig. 7. Typical Surface Plate Instruments, showing:

(1) Johannson type long gage blocks.
(2) Assorted straight edges.
(3) 1", 2" and 3" micrometers with standards.
(4) Vernier depth gage.
(5) Johannson type thin gage blocks.
(6) Hoke type Standard Set gage blocks.
(7) Sine block.
(8) Angle plate.
(9) Height gage with dial indicator attached.
(10) Flush pin gage.

Indicator is here shown in position to indicate across pin and flush surface of flush pin gage.

(U. S. Army photograph)



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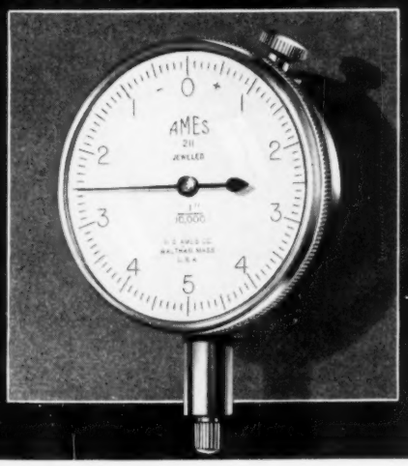

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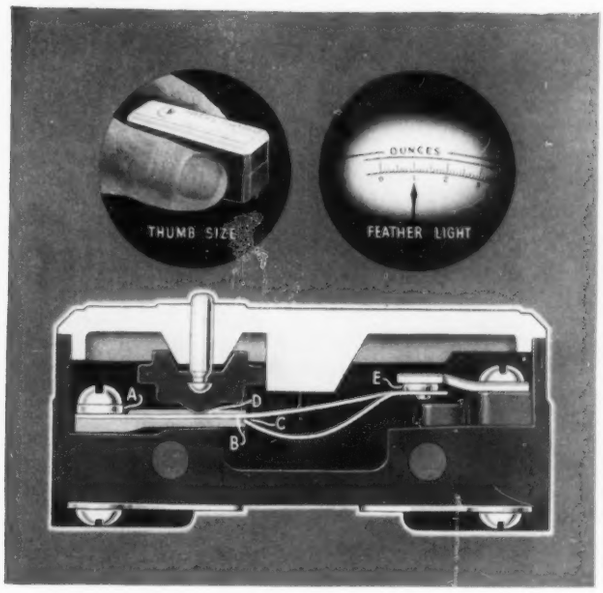

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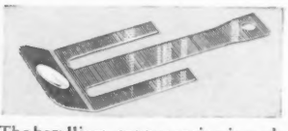
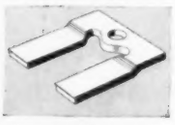
- **Longer switch life than you will ever need**
- **Absolutely precise and accurate repeat operation**
- **40 grams contact pressure—lightning-fast contact action**

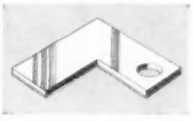
The Micro Switch design incorporates features that provide desirable performance characteristics not generally found in snap-action switches . . . The heat-treated beryllium-copper spring bends in the same direction as the operating plunger—no reverse bends—no "oilcan" action . . . gives longer switch life—accurate repeat action—increased contact pressure—lightning-fast action—millions of operations on minute movement and force differentials. It is the choice of design engineers for all types of sensitive instruments.



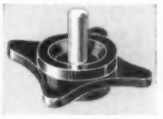
The beryllium-copper spring is made in one piece. It is gauged to an accurate .0085" thickness; has high resistance to fatigue. Ends of compression members are finished to provide an extremely low friction bearing. Contact end of the spring is fitted with a riveted radius type contact of 99.95% fine silver. It moves at a speed of 3 1000ths to 5 1000ths of a second with a rolling action and extremely high pressure.



Short spring members pivot in patented V-grooves of this sturdy brass anchor. Note the special shape of these grooves, which reduces friction to a minimum.



Stationary contact is a flat inlay of 99.95% fine silver. This construction assures ample over-load capacity and maximum heat dissipation.



Operating plunger is a highly polished stainless steel pin imbedded in an accurately moulded star-shaped Bakelite head. Provides long over-surface path to live parts, thus insuring freedom from electrical leakage. Plunger head cannot rotate within the housing, insuring against any variation in point of operation.

If you would like to know more about the Micro Switch, send for the two Handbook-Catalogs illustrated here—No. 60, which covers Micro Switches in general; and No. 70 which deals with specific Micro Switches for use in aircraft.

Micro Switch is a trade name indicating manufacture by Micro Switch Corporation

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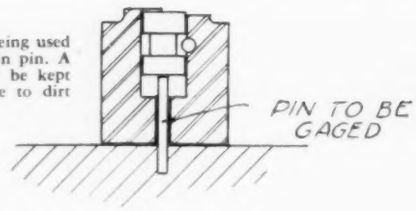


Fig. 9. Flush pin gage being used in inspection of long thin pin. A gage of this type must be kept clean as it is vulnerable to dirt in flush pin cavity.

the gage and measuring first the length of the pin and then the thickness of the body—first over one "step" and then over the other. The measurement of the pin, less one measurement of the body, shows one limit of tolerance; and the pin, less the other measurement of the body, the other limit. This procedure sounds considerably easier and as a matter of fact it is, but it is not as accurate as the surface plate method. The reason is that there is necessarily an accumulation of errors when more than one reading is taken. For instance, if we allow an error of 0.00005 in reading accuracy in both the indicator and the supermicrometer, then in the surface plate method there is one reading to take for every two in the micrometer method and the chance for error is doubled.

Some gages, however, are necessarily measured this way. Consider a gage to inspect the height of a pin 1.000" high and 0.050" in diameter. It would be difficult to inspect the gage in Fig. 9 otherwise than by direct measurement of parts. If final accuracy of 0.0001 or smaller is desired in the gage, the parts should be measured on a comparator or measuring machine reading to 0.00001 or 0.00002.

Flush pin gages may sometimes be provided with a master, but this is unusual unless the gage is particularly complicated. Direct measurement is usually simpler.

Compound Flush Pin Gages

Compound flush pin gages are inspected in exactly the same manner as ordinary flush pin gages.

Plate Gages

Plate gages are measured by clamping to a parallel or angle iron or attaching to a magnetic block, indicating one surface level and then comparing all gaging surfaces to gage blocks and finally calculating.

Indicating parallel should always be performed on the longest straight surface unless there are two surfaces not adjacent which should be in the same plane, in which case these should be indicated in setting up the gage.

There always is the tendency on the part of the inexperienced inspector to inspect the gage by measuring *BD*, *AD*, and *CD* and calculating *AC* and *AB*, as shown in Fig. 3. This is a dangerous practice (even though surface *D* seems good and even though there is reason to believe that the gage was manufactured with *D* as a master surface) because final lapping may have changed parallelism. An experienced inspector may sometimes resort to this method, but only after assuring himself that the usual method would not do in the particular case and that all surfaces are parallel as far as measureable.

This type of gage lends itself readily to inspection on

Fig. 10. Contour Measuring or Projection Machine bring used to determine contour of production item. Image of item on table is thrown on round screen at eye-level. (U. S. Army photograph.)

contour measuring machines. This inspection is rapid and capable of high accuracy. The accuracy depends upon the magnification which is used. In general use, accuracies in measurement of 0.0002" may be attained. Fig. 10 shows a contour measuring machine in use (though not for measurement of a gage but of a production item).

Gooseneck Gages

Gooseneck gages are normally inspected on a surface plate, the type of set-up being determined by the gage being checked. Again, the principle holds that the inspection of an offset gage entails the establishment of a difference in dimensions. A gage as shown in Fig. 5 may be set up on a surface plate with the length of the gage set vertical on the surface plate and clamped to an angle plate ("8" in Fig. 6). In this case, the gage blocks are fitted under one end of the gooseneck gage when the other gage surface is flush with the surface plate.

Combination Gages

So many and varied are the types wherein an offset dimension can be inspected in conjunction with some other gage that all cases become particularized. The inspection job will normally be performed on a surface plate, each particular type requiring a procedure of its own.

INSTRUMENT SOCIETIES CALENDAR*

CITY	DATE	PLACE	SPEAKER	SUBJECT	SOCIETY	SECRETARY
Atlanta	Sept. 28	Physics Bldg., Ga. Tech	Organization Meeting			M. V. Davis, P. O. Box 1714
Baltimore	Sept. 18	Maryland Academy of Sciences	Prof. from Johns Hopkins Univ.	Instrumentation Courses	Baltimore Industrial Instrumentation Society	Fred Pullen, Bethlehem Steel Co., Sparrows Point, Md.
Chicago	Oct. 5	St. Clair Hotel	H. C. Rowe, Rowe Radio R. L. Co.	Unique Electronic Instruments	Chicago Society for Measurement & Control	Carl Hope, 2626 W. 31st Blvd., Chicago, Ill.
Hartford	Sept. 15	Auditorium, Hartford Electric Light Co.	I. A. Hunt, Federal Products Corp.	Gaging	No Name Announced (Organization Meeting)	Stephen J. Zelle, Whitney Chain & Mfg. Co., Hartford, Conn.
Newark	Oct. 6	Essex House	John H. Miller, Weston E. I. Corp.	Principles of Electrical Measuring Instruments	Society for Measurement & Control (N.J.)	R. F. Robey, 409 Orange Ave., Cranford, N. J.
New York	Sept. 29	Roosevelt Hotel	Organization Meeting		No Name Announced	George Kauer, Jr., 4155 Case St., Elmhurst, L. I.
Philadelphia	Sept. 16	Engineer's Club	Organization Meeting		No Name Announced	H. J. Boyce, Eng. Dept., Philadelphia Electric Co.
Pittsburgh		No Meetings Announced at this time			American Society for Measurement & Control	L. M. Susany, c/o Carnegie Institute, 4400 Forbes St., Pittsburgh

*Meetings begin at 8 P.M., Dinner served at 6:30 P.M.

Dynamic Unbalance—Its Cause, Effects and Correction*

By GEORGE C. LAWRIE
Tinius Olsen Testing Machine Co., Philadelphia, Pa.

TODAY the emphasis is on speed and still more speed. In many cases its attainment requires the development of improved methods and new equipment. Inseparably tied up with speed is the problem of balancing. Increase speed and you cannot prevent a corresponding increase in the necessity of balancing. Unfortunately, however, far too many fail to recognize this fact—thereby augmenting the job of locating the real source of many of the difficulties arising from increased speed.

Locating and correcting unbalance without proper equipment and a knowledge of the problem is like hunting for the proverbial needle in a haystack. If you have nothing else to do, you can take the haystack apart, bit by bit; but in these days we would better use a magnet and not waste valuable time.

Smoothness and quietness of operation of all machinery depends to a large degree upon balance. Excessive unbalance causes noise, wear on bearings, increased oil consumption, power losses, as well as depreciation due to detrimental effects of vibration in loosening joints and weakening structural members. The degree to which these evils become noticeable increases with increase in speed, the actual shaking forces increasing as the *square* of the speed.

The amount of unbalance which may be detrimental depends upon many factors. In some parts or assemblies unbalance may be harmful or undesirable at even a few hundred revolutions per minute, especially if the part is structurally weak and is not adequately supported.

The fact that a complete machine bolted to a solid foundation does not seriously vibrate is not necessarily evidence that the rotating parts are balanced; nor does it prove the presence or absence of damage being done by unbalance in the rotating parts. A heavy foundation and massive construction of the machine may absorb the vibration and remove the symptoms of unbalance, but all of its harmful effects may still exist. For example, an electric motor whose armature is unbalanced may run without evidence of unbalance at a certain speed, with the motor located on one particular foundation or support; at other speeds, or if the motor is moved to another support, vibration may appear. The reason for this is that all structures have a certain natural period of vibration. The motor housing would have its own natural period, and the support would have another natural period. Unbalance in a rotating armature sets up a cycle of vibration for each revolution. If the natural periods of vibration of the motor housing and of the motor support happen to be the same as the speed of rotation of the armature, this is a synchronous speed at which maximum vibration will occur. If the natural periods of vibration of motor housing and support are not the same as the speed of rotation, the degree of vibration may vary all the way down to zero, at which point the vibration periods of the two members may oppose each other. Outward evidence of vibration may then be practically eliminated, but within the machine itself the detrimental effects of vibration still exist.

The fact that a finished machine does not vibrate is not necessarily an indication that no unbalance is present. The one sure way to know is to check the rotor separately on a suitable balancing machine.

The selection of balancing equipment to be used is of utmost importance. The annoyance and uncertainty experienced with home-made balancing machines is due, in most instances, to the many variable factors entering into their design, construction and operation. These variable factors may confuse and mislead the user. A machine that is improperly made or operated may register perfect balance when the part is unbalanced, or it may register the location or amount of unbalance at a totally incorrect position or value. Unless the operator is familiar with all the characteristics of such a machine (and, incidentally, these characteristics may change radically with a change in size or shape of part) he may obtain an incorrect reading and find that it is difficult or impossible to locate the source of error and to obtain a satisfactory balance.

Balancing equipment as manufactured today is designed to show quickly the exact location and amount of static and dynamic unbalance, so that proper corrections can be applied without any guesswork, thereby minimizing the cost of balancing parts and assuring the engineer that the rotating part is actually balanced within the required tolerances.

STATIC BALANCING

Broadly, balancing may be classified as either static or dynamic. Let us look for a moment at static balancing. This is a term applied to the process of balancing with the body at rest, or rotating so slowly that centrifugal forces are not appreciably effective. Static unbalance can be determined by using level ways or rollers, or by rotating the body in a balancing machine designed for this purpose. Correction may be made by adding or removing material at one point. Static balancing may determine the amount and angular *plane* in which the unbalance is located, but the correction is usually made irrespective of its location along the axis of rotation.

Balancing by the use of level ways or rollers, formerly universal practice, has been found totally inadequate for close balancing. Such methods are not adequately sensitive. Level ways or rollers consume an excessive amount of time and can be used only for static balance. They give an approximation of the angular position but no indication of the amount or location of unbalance in a direction parallel to the axis. If means such as these were used to balance a comparatively long part such as an electric motor armature, the results probably would be misleading. The unbalance might be near one end but the use of level ways would not give any indication whatever of its position in a lengthwise direction. The operator might correct for this unbalance by adding the necessary weight on the opposite side of the armature, so that it would appear balanced on the level ways, but he might add it at the wrong end of the rotor. By so doing he would introduce a dynamic couple which might be far more detrimental than the original static unbalance.

This reason alone is sufficient to confine the usefulness of static balancing to parts which are relatively short with relation to their diameter, or where lengthwise position of static unbalance is known.

DYNAMIC BALANCING DEFINED

Now let us briefly consider dynamic balancing. Dynamic balancing requires the rotation of a body at suitable speed so that the centrifugal forces due to unbalanced distribution of weight may be located and measured. The amount and position of dynamic unbalance can be determined only by rotating the body in a dynamic balancing machine, which indicates both the angle and amount of the disturbing centrifugal unbalanced force or force couple. A dynamic balancing machine will also indicate static unbalance and when static unbalance alone exists, correction can be made at one point only. However, when dynamic unbalance exists, correction cannot be made by adding or removing material at one point but can only be accomplished by correcting at two or more points to form a corrective couple.

*Presented before the Hamilton (Ont.) Chapter and before the Toronto Chapter, of the American Society of Tool Engineers.

At this point it is well to remember that when a rotating body is properly corrected for dynamic unbalance it is also in static balance, but the converse is not always true, that is, a body may be in perfect static balance but still be far out of balance dynamically.

Essentially, the basic cause of unbalance is lack of symmetry of mass distribution about the axis of rotation of the body. This lack of symmetry may result from several legitimate causes. One is design—both good and bad. In many cases it is impossible to provide correct static and dynamic balance, due to the functioning of the member or members. More often, however, large unbalanced forces are caused by poor design where the designer has not had sufficient knowledge or experience along this line to provide adequately for unbalanced forces. Even in cases where the design may be good, the lack of uniform density of material used may cause rather large unbalanced forces to be set up. These must be corrected before it is possible to obtain smooth running.

Eccentricity of bearing surfaces and inaccuracies in machining are frequent causes of unbalanced mass distribution. Unmachined surfaces, in such parts as forgings or castings, cannot be held concentric with the axis of rotation within close dimensions, hence invariably tend to set up unbalanced centrifugal forces.

Most rotating bodies are made up of an assembly of a number of parts put together in various ways, and the assembly and fit of the various parts with one another determines to a large extent the resulting unbalance in the rotor. For instance, in an electric motor armature it is physically impossible to obtain absolute uniformity in the placement of the windings with respect to the axis of rotation, hence for smooth operation it is imperative that the armature be balanced after winding. Armature laminations may be stacked on the shaft slightly out of square with the axis, and such assembly will set up a surprising dynamic unbalance. The reason for this will be shown a little later. Looseness of parts when mounted on the shaft, even though the individual parts may be in perfect balance, may set up a heavy unbalance in the assembled rotor. Think of a pulley, perfectly balanced on its own axis, but placed on a shaft which fits loosely in the bore. It may be held in place by set screws or a key, but either way will force the pulley off center. The unbalance set up will be equal to the weight of the pulley multiplied by the eccentricity.

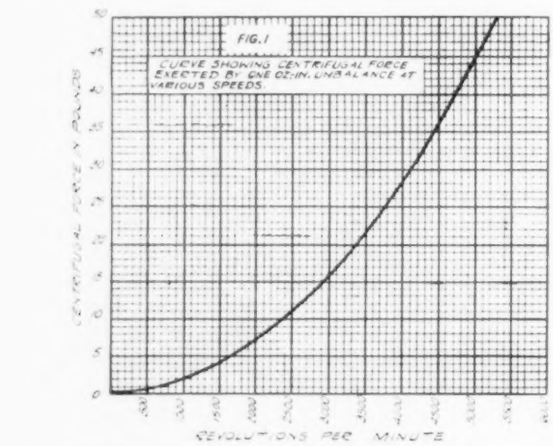


FIG. 1
CURVE SHOWING CENTRIFUGAL FORCE EXERTED BY ONE OZ-IN. UNBALANCE AT VARIOUS SPEEDS
CENTRIFUGAL FORCE IN POUNDS
REVOLUTIONS PER MINUTE

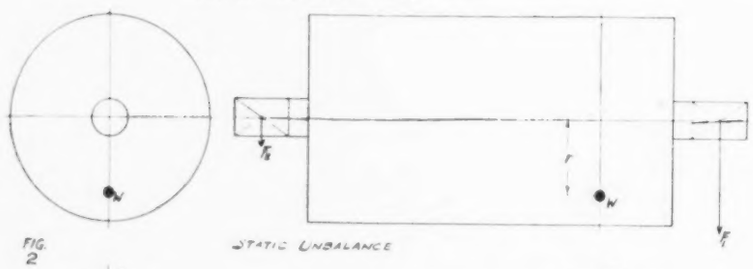
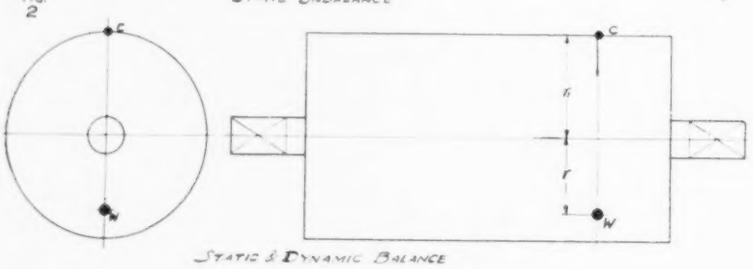


FIG. 2



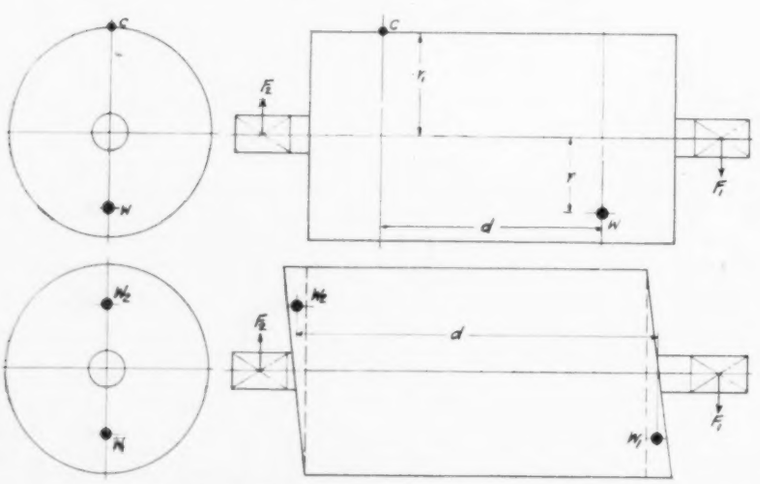


FIG. 3. STATIC BALANCE & DYNAMIC UNBALANCE

Even such parts as set screws themselves can set up an appreciable unbalance, particularly in high-speed rotors, if no attempt is made to counterbalance the extending length of the set screws. There comes to mind a rather amusing incident. A high-speed squirrel-cage rotor had been sent in to us for balancing. It had a long shaft extension and at the extreme end was a large square-head set screw, used for holding a bit in the hollow end of the shaft. The set screw was at least twice as long as necessary and, due to its position on the extended shaft, naturally set up a heavy shaking force. On checking the rotor in a balancing machine it was found that the unnecessary length of the set screw was responsible for most of the vibration, but due to its distance from the planes of correction, sufficient balancing corrections could not be made without ruining the electrical characteristics of the rotor. By substituting a hollow-head set screw of correct length, a good balance was easily obtained —and safety of operation was considerably improved. We called our customer by 'phone to explain that we would have to substitute the short set screw in order to balance the rotor. He told us that it would be all right for us to put in the short set screw while we balanced the rotor, and then they could put in the regular set screw again when they received the rotor. You can see that he completely missed the point, and the moral of this little story might well be: don't alter a balanced rotor and expect it to remain balanced.

Perhaps the importance of dynamic balancing will be better appreciated by referring to Fig. 1 which shows a curve of the centrifugal force exerted by one ounce-inch of unbalance at various speeds. As mentioned a while back, centrifugal or shaking force increases as the square of the speed which gives us the parabolic curve shown.

ordinates are centrifugal force in pounds. It is interesting to note that this comparatively small unbalance of one ounce-inch exerts a force of only slightly over one ounce at a speed of 200 r.p.m. but, if a rotor operating at 5000 r.p.m., it will exert a force of almost 45 lbs. If you double the operating speed to 10,000 r.p.m., which is not an uncommon speed today, then this force is four times greater or nearly 180 lbs.

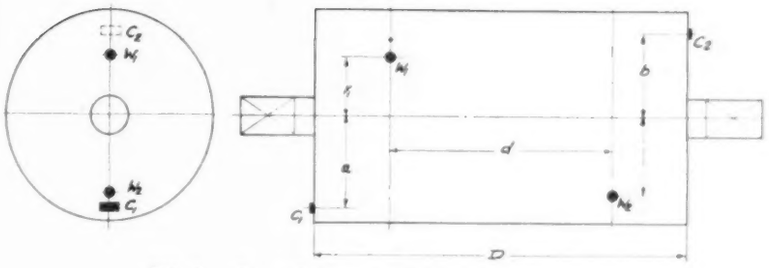


FIG. 4. STATIC & DYNAMIC BALANCE

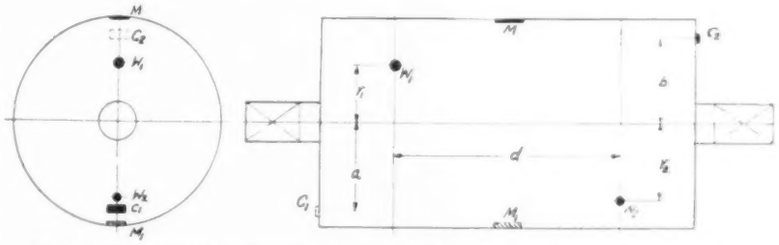


FIG. 5. CORRECTION FOR STATIC & DYNAMIC UNBALANCE IN THE SAME AXIAL PLANE

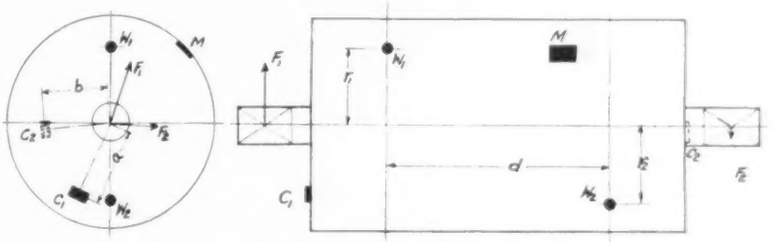
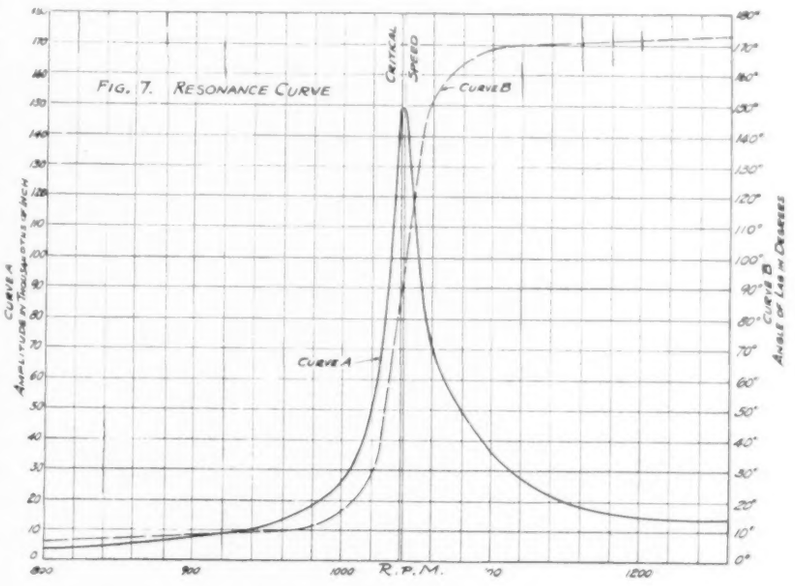


FIG. 6. CORRECTION FOR COMBINED STATIC & DYNAMIC UNBALANCE



PRINCIPLES OF BALANCING

In order to simplify the explanation of the general principles of balancing, we shall use sketches showing a simple cylindrical rotor which may be unbalanced as a result of non-symmetrical mass distribution due to any of the causes which we mentioned a while back.

Fig. 2 shows a rotor which we assume to have a single unbalanced weight W concentrated at a distance r from the center of rotation of the cylinder. This is a pure static unbalance and will create shaking forces at the bearings on the order of F_1 and F_2. Such an unbalance may be corrected by placing a correction weight C at a distance r_1 from the center of rotation diametrically opposite the unbalance W and of course in the same plane normal to the axis of rotation. Observe that the weight C may be less in value than the actual unbalance but at a larger radius than the unbalance, and perfect balance will be secured as long as the product of the correction weight multiplied by the radius is equal to the unbalance multiplied by its radius. When the correction is properly applied the forces at the bearings F_1 and F_2 will disappear.

If this same rotor were balanced on level ways, the operator could not determine longitudinally the proper plane in which to place the correction and might place it at or near the other end of the cylinder as shown in Fig. 3, thereby introducing a dynamic couple which may be more serious from a vibration standpoint than the original unbalance. The lower part of Fig. 3 shows why a heavy dynamic unbalance may result in the case of squirrel-cage armature from improper stacking of the laminations on the shaft. The condition is the same as if the part had been corrected for static unbalance on the level ways and the correction had been placed at the wrong end. Such a condition, of course, would indicate perfect balance on static level ways so it is easily seen that this method is misleading and not at all satisfactory for rotors of any length operating at high speeds.

For a condition as just discussed, the rotor can be balanced, both statically and dynamically, by the introduction of an equal and opposite force couple. See Fig. 4. The corrections do not necessarily have to be placed in the same planes normal to the axis of the rotor as those in which the unbalance occurs, but they must be placed in the same axial plane. If the unbalance is purely dynamic (i.e., laminations stacked improperly) or if corrections were made at the wrong end of the rotor in statically balancing, then the two elements of the couple W_1 and W_2 are equal and the turning moment of the couple is the product of one element multiplied by the distance between the two elements represented by d.

In correction, weights may be added in two other planes, such as at the ends of the cylinder, these corrections indicated by C_1 and C_2, but the turning moment of this couple must be equal to the original unbalance couple, that is, for instance, $C_1 \times a \times D$ is equal to the original unbalance moment. Notice in the end view that the corrections are in the same axial plane. When such corrections are effected, the rotor will be in perfect static and dynamic balance and will run without vibration.

Fig. 5 shows the condition of pure dynamic unbalance plus static unbalance in the same axial plane as the dynamic couple. Corrections may be made by two methods. One is to make a single correction M_1 to compensate for the static unbalance M and then make two additional corrections to take care of the remaining dynamic unbalance as explained in connection with Fig. 4. These corrections would be C_1 and C_2, not necessarily in the same planes as

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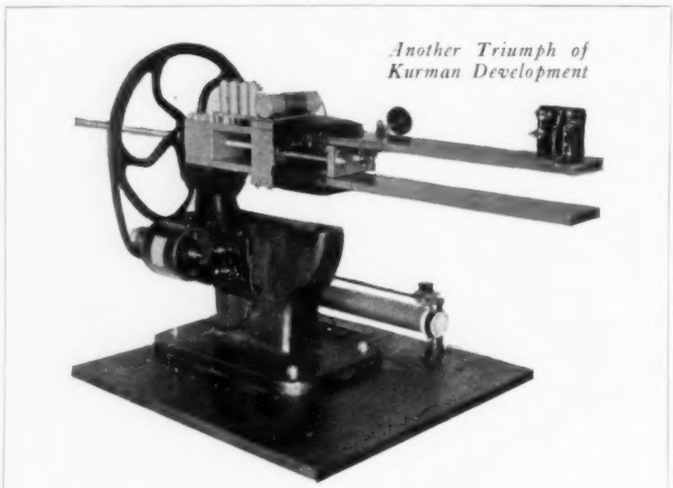

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A reed tachometer indicates the frequency of vibration at all times.

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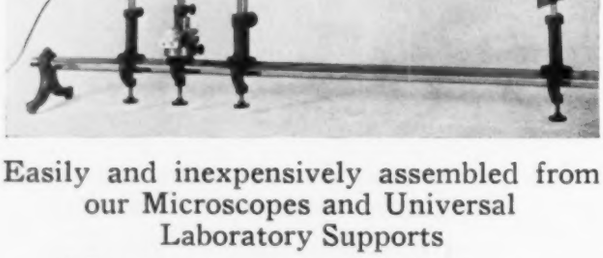

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the unbalance but made wherever convenient. The other method is to take care of both the static unbalance and the dynamic couple by means of only two corrections in planes wherever convenient. In the case shown by Fig. 5, it would mean simply that the values of C_1 and C_2 would be different even though the radii of the two correction weights would be the same. Both correction weights, however, would still be in the same axial plane as the unbalanced dynamic couple and the static unbalance. When the correction weights are such that moments of both unbalance and correction forces, taken about either of the two correction planes, are zero, perfect static and dynamic balance results—even though only two correction weights were added.

Fig. 6 shows the most commonly encountered condition where there is a combination of static and dynamic unbalance but the static is not in the same axial plane as the dynamic unbalance. This condition is what makes it so difficult to locate the proper amounts and angles of correction weights without having properly designed balancing equipment. W_1 and W_2 represent the two elements of a dynamic unbalance and M represents a static unbalance in the same rotor but at an angle other than that in which the dynamic couple exists. The static unbalance and the dynamic couple remain in the same positions relative to one another as the body rotates. Hence the resultant shaking forces at the bearings caused by this combination remain constant for a given speed and rotate at the same speed as the rotor. They are represented by F_1 and F_2 and are actually the resultants of all elementary centrifugal forces acting in the body.

Unbalance corrections usually cannot be made in the planes of the bearings, so we must select two other planes. Since the axial locations of the bearing surfaces are arbitrarily chosen in the design of the rotor, it will be obvious that any two arbitrarily selected planes will also contain two rotating resultants, although they will not necessarily be of the same value nor in the same phase position as the forces at the bearings. If these two rotating resultants in the planes selected for correction are neutralized, then the rotor will run without vibration. The fact that the static unbalance is not in the same plane as the dynamic unbalance couple causes the shaking force F_1 and F_2 at the two bearings to occur in some such angle as indicated in the end view which may be entirely different from either the static unbalance angle or the dynamic unbalance angle. The corrections C_1 and C_2 necessary to apply in the two planes of correction, which may be chosen for instance at the ends of the cylinder, will not be directly opposite the forces F_1 and F_2 at the bearings. This is indicated also in the end view and the corrections may have to be applied at two angles to bring the rotor into balance. However, when the proper locations for the two correction weights are determined, the application of these two weights will result in a perfect static and dynamic balance of the rotor.

The function of the balancing machine is to measure the two unbalanced resultants in the selected correction planes and determine their angular locations. This may be done in a number of different ways, each having its own advantages and disadvantages. However, all methods (except static balancing on level ways) are based on vibration transmitted to the bearings supporting the rotor. The balancing machine must be able to indicate from the vibrations at the bearings the proper angle and amount of the resultant in each of the two correction planes, and consequently the angle and amount of the corrections to be made in these two planes.

The relation of the natural period of vibration of the supports for the rotor, to the running speed during the balancing operation, is of great importance. This will be readily seen by examination of a typical vibration amplitude curve plotted against speed, as shown in Fig. 7. Here the ordinates for curve A are the amplitude of vibration in thousandths of an inch and the ordinates for curve B are angles of lag in degrees. Abscissas for both curves are revolutions per minute. It will be noted that at the critical speed the amplitude of vibration increases rapidly, is a maximum at the actual critical speed and falls off

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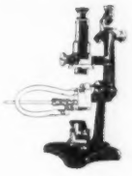

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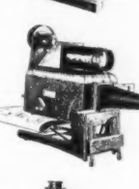

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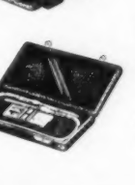

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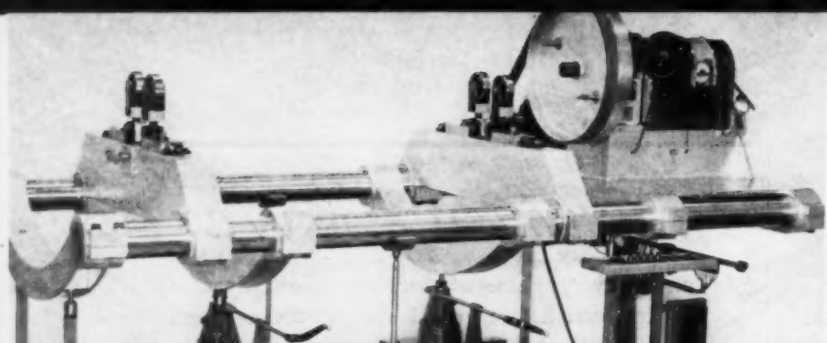


Fig. 8

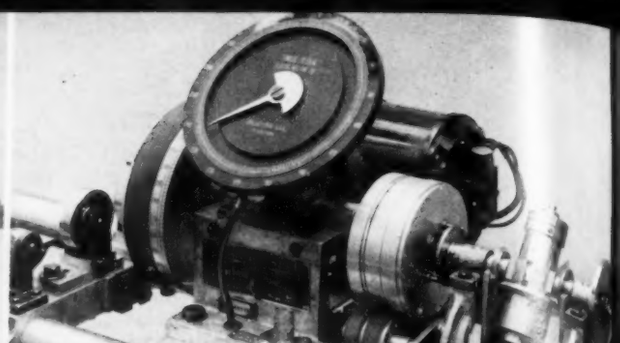


Fig. 9

rapidly after passing through the critical. It will be noted also that the angle of lag curve, *B*, changes rapidly in passing through the critical speed and the actual change is almost 180° upon passing through the critical. This will explain why it is so difficult to obtain a consistent or steady reading, when attempting to balance in a critical speed. A slight change in speed results in a large change in amplitude of vibration, as well as in a large change in the angle of lag of cause and effect of the unbalance. This is the chief reason why practically all present-day machines operate at some speed other than the critical, either above or below, since in either case slight variations in speed, which are unavoidable, do not cause any serious change in the amplitude of vibration nor the indicated angle of unbalance.

EXAMPLES OF BALANCING MACHINES

Early efforts in dynamic balancing were to rotate the work in flexibly mounted bearings and mark the shaft to indicate the high spot. This method was not positive. It depended upon how close the operating speed was to the natural period of vibration, or the critical as termed in Fig. 7. Hence the lag angle was indefinite and the amount of unbalance entirely unknown. Corrections were made on a purely cut-and-try basis, and such corrections always influenced both ends, so that when proper corrections were made in one plane to eliminate vibration at the bearing, the second correction for the other bearing might upset the work done in the first plane, and so on for an indefinite number of corrections. Then came a succession of balancing machines of various types, some crude and slow to operate, and all with varying limitations and degrees of accuracy.

Today balancing machines may be divided into two main classes, the compensating type and the indicating type. In the former type a compensating unbalance may be set up in the machine, to neutralize the unbalance being sought in the part. The indicating type simply registers, in one form or another, the vibrations caused by the work when rotating and shows the phase angle of the vibrations.

Let us look at some representative modern machines of both types. Brief explanations of their construction and functioning will bring out how an accurate static and dynamic balance may be easily and quickly obtained.

Fig. 8 shows an example of the compensating type: the Olsen Type S Static Dynamic Balancing Machine. On a substantial base are located two pivot locking brackets which are adjustable along the base. From this base four vibratory support rods extend up and carry the vibratory cradle on which the work is mounted. Two pivot brackets, also located on this cradle, are readily adjustable along the cradle so that they can be placed in the two planes selected for correction. At the headstock end, a large bracket carries the motor and driving pulley and the unbalance compensating mechanism. The part to be balanced rests on four support rollers, individually adjustable, and a suitable drive adapter on one end of the shaft engages two flexible type drive pins in the pulley. It will be noted that when either of the two locking pivots is engaged, the cradle is restrained to vibrate in a horizontal plane about the locked pivot as a center. Since only unbalances, or resultants of unbalances, outside of the plane of the locked pivot, can cause vibration of the cradle, any resultant unbalance occurring in the plane of the locked pivot cannot cause vibration of the cradle since it has no moment along the cradle with respect to the center of oscillation. Thus, if the two locking pivots are placed in the two planes selected for correction, when we lock one of them we eliminate the effect of any unbalance in that particular plane, so that we are able to read the remaining unbalance in the part, which can be corrected in the second plane. Then, by interchanging pivots, the unbalance in the first plane can be obtained.

In this type, the headstock is really the heart of the machine, so we shall take a closer look at the compensator with its operating mechanism as shown in Fig. 9. Complete control of this compensator is from a conveniently located switchboard, and is such that both the angle and the amount of unbalance in the compensator may be adjusted at will while the machine is running. The compensator is connected to the main driving spindle of the machine through a special type of magnetically-controlled friction clutch which will be described later. This clutch is normally engaged so that the compensator will run in synchronism with the pulley and hence with the work being balanced. The spiral gear drive from the main spindle also operates the angle indicating pointer on the dial just in front of the headstock in synchronism with the work. The sparks appearing on this dial show the relative positions of unbalance in the work and the compensator unbalance, making the balancing operation visual.

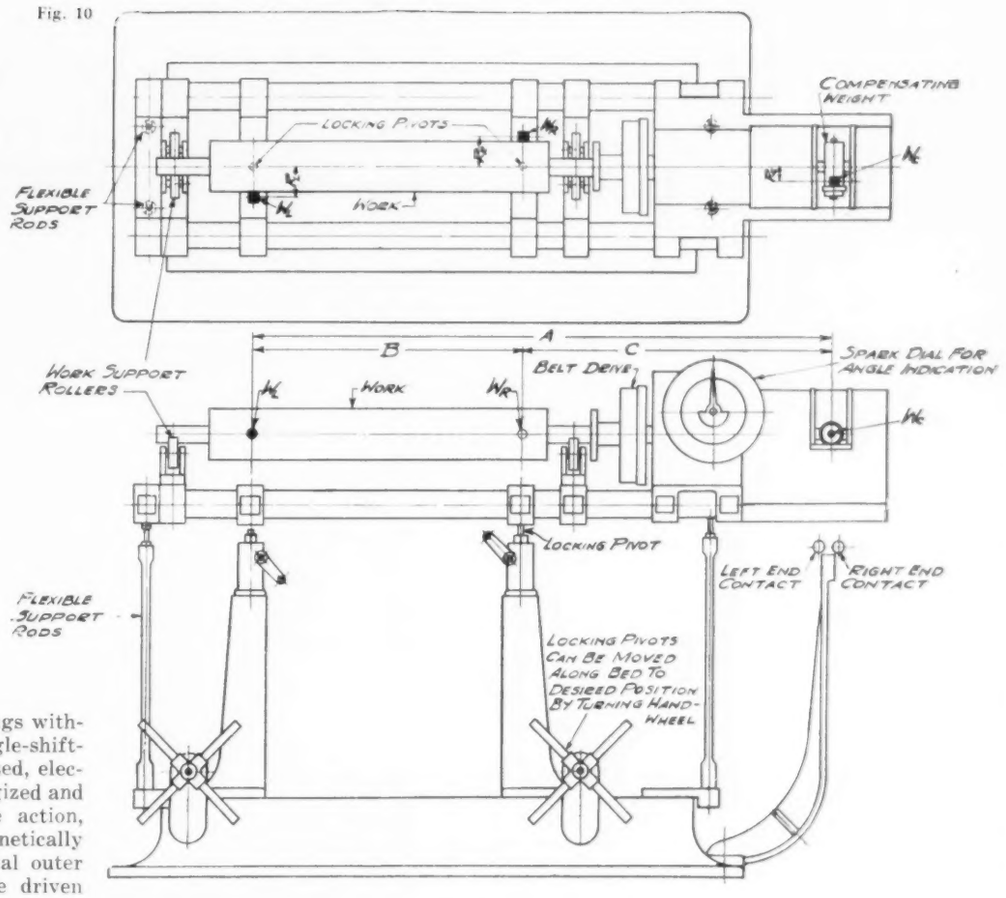
The dial really consists of a rotating spark gap in a high-tension spark system. As the work is rotated on the vibratory cradle, unbalance in the work will cause forced vibrations of the cradle in synchronism with the rotational speed. Contacts are provided beneath the cradle which "make" at one extreme of each forced vibration. During the length of time that this contact is closed the pointer has made a partial rotation around the spark dial and the spark between the end of the pointer and the ring on the dial appears as a blue arc of sparks which denotes roughly the position of the unbalance. This arc of sparks will appear at the same position on the dial for each revolution of the machine since it is caused by actual forced vibration due to the unbalance.

A switch on the control panel enables the operator to switch on another contact which is controlled by a cam fixed to the outer end of the compensator shaft. This cam has a projection on it which makes a single contact for each revolution. The angular location of the single spark resulting from this contact may occur at any place on the dial depending upon the actual angular relation of the compensator to the main driving spindle of the machine. This angular relation may be adjusted while the machine is running by means of the magnetically-controlled friction clutch. When the compensator is adjusted angularly the single spark will appear to move around the spark dial in one direction or the other depending upon which way the

compensator is being shifted relative to the rotation of the machine. If the single spark which denotes the angular position of the compensator is shifted around the spark dial until it is directly opposite the center of the arc of sparks caused by the unbalance in the work, the compensator is then in the same axial plane as the unbalance. It exerts an unbalance moment in a direction opposite to the unbalance in the work and thus neutralizes vibration of the cradle. When the compensator unbalance is thus adjusted, the arc of sparks on the dial will either disappear completely or break up into scattered sparks all over the dial depending upon the adjustment of the contact points beneath the cradle.

To explain the method of shifting the compensator angularly while the machine is running, we shall briefly describe the operation of the special clutch. The driven member of this clutch (which is fixed in relation to the compensator shaft) is normally engaged to the driving member by means of coil springs within the clutch assembly. When the angle-shifting button on the switchboard is pressed, electromagnets within the clutch are energized and the clutch disengaged. By the same action, angle-shifting clutch rollers are magnetically forced into contact with the cylindrical outer surfaces of the clutch members. The driven member has two steps on its surface, one step smaller and the other step larger than the driving member. There are two sets of shifting rollers, one contacting the driving member and the smaller step on the driven member; the other contacting the larger step on the driven member. Only one set can contact at a time, depending upon which of the two angle-shifting buttons is pressed. With the clutch disengaged and either set of shifting rollers engaged, the two members of the clutch will continually change their angular relation to each other as long as the angle-shifting button is held down. When the button is released the clutch instantly engages and the compensator again runs in synchronism with the work and its new angular location is shown by the single spark on the dial.

Fig. 10



So much for the *angular* shift control. Now to explain the control of the *amount* of unbalance compensation while running. The compensator consists of a hollow cylinder with its axis normal to the axis of rotation as shown in Fig. 9. Inside the compensator, a weight is carried on a screw which extends the length of the compensator barrel and projects at both ends. To one projecting end of the screw a beveled friction disk is attached; to the other end a graduated cap for reading fine units of unbalance. An index on the weight aligns with graduations along a slot in the side of the barrel. The barrel and cap are graduated in ounce-inches, or other units as required, and are read as an ordinary micrometer: the coarse readings on the barrel and the fine readings on the cap. Two buttons on the control panel govern the increase or decrease of unbalance in the compensator. Pressing either button causes a yoke to be forced magnetically in an end-wise direction so that one of two stationary beveled disks will engage the beveled disk on the compensator screw. As the compensator rotates, the planetary action of the compensator screw disk rolling around the stationary yoke disk will cause the screw to turn, thereby moving the compensator weight radially and changing the unbalance in the compensator.

In order to explain how this compensator is used to determine the angular position and amount of unbalance in each of the *two* planes, we refer to the schematic diagram, Fig. 10. Note that the pivots are adjusted to the two planes in which it is desired to measure and correct the unbalance. In the plan view the two resultant unbalances are represented by W_L and W_R. The compensating unbalance is shown by W_C. It will be seen that when the compensator has been adjusted to the proper angular plane by noting the sparks on the dial, then it is only a matter of increasing unbalance in the compensator until its moment about the locked pivot is equal to the moment of the unbalance in the plane of the open pivot about the locked pivot. This is shown in the plan view. When this condition is reached so that, for instance, with the right pivot locked $W_L \times R_L \times B$ will equal $W_C \times R_C \times C$. Then all vibration of the cradle ceases since the moments of the two effective unbalances are equal and opposite. The value of W_C–R_C is known since it was created by the operator and the distances A, B and C may be measured readily on the machine, hence the unknown in the foregoing equation is W_L–R_L. This is expressed in ounce-inches or other convenient units and, when the radius at which the corrections are to be made is selected, the proper correction weight is easily determined. Its angular position is determined by the angular position of the compensator since both must be in the same axial plane.

The same theory applies when determining the unbalance in the right correction plane with the left pivot locked.

This machine is used for both production balancing and general-purpose work where rotors of various types and sizes must be handled. It gives readings of unbalance in ounce-inches or other correction units without the necessity of making a calibration. It is simple to change over when handling parts of various sizes. However, when this machine is used for production balancing, for instance on crank shafts, there is always the possibility that the inaccuracies in the correcting will exceed the allowable tolerances of unbalance so that it is desirable to recheck the shaft after it has been corrected. Rather than tie up the

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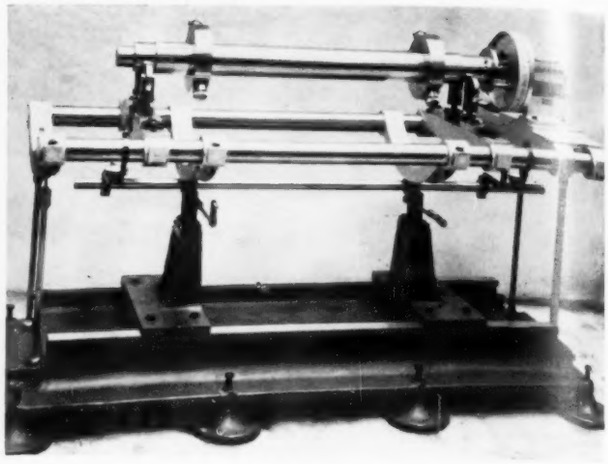

Fig. 11

balancing machine for this checking process, it is usually desirable to place the shaft in a special *checking type of machine* such as that shown by Fig. 11. This machine is constructed somewhat along the lines of the balancing machine but has no compensator. Instead, it simply indicates the amplitude of vibration and this amplitude may be readily calibrated so that the indicators will show a definite reading for the allowable unbalance tolerance. Checking machines are fast in operation and will handle two to three times as many shafts as can be put through a balancing machine.

Representative of the *indicating type of machine* is the Olsen Type EO Static Dynamic Balancing Machine, Fig. 12. Used mainly for the balancing of smaller parts, this type is simple in construction and extremely sensitive. The work is supported on a vibratory cradle on support rollers as in the Type S but this machine has no compensator and the driving motor is not mounted on the vibratory cradle. Instead, the work is driven by means of a universal joint drive from the cradle to the fixed headstock of the machine. As the work rotates on the cradle, vibration of the cradle about either of the locking pivots actuates magnetic pick-ups secured to the base at the rear of the machine. These pick-ups generate an alternating current proportional to the unbalance being measured. The phase relation of this alternating current to the rotation of the part being balanced is a measure of the angle of unbalance. In order to

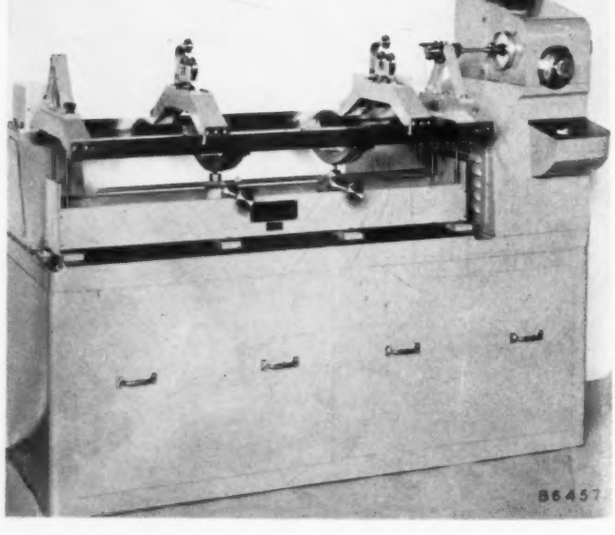

Fig. 12

determine this phase angle, a special mechanical contact type of rectifier, located in the headstock of the machine, is operated by a cam rotating in synchronism with the part being balanced. This cam alternately opens and closes a contact every 180°, so that for a given setting of the contacts—or commutator as it is called—the direction of the current from the pick-up coils to the indicating instrument is reversed every half turn of the part being balanced. The angle is determined by the phase angle of the commutator as shown on the dial which is graduated in degrees. This angle is simply transferred to a dial, also graduated in degrees, which is located on the spindle of the machine. If the machine is stopped and turned so that this dial shows the same angle as that indicated on the commutator dial, then the heavy side of the part will show either to the front or rear horizontal plane through the axis of the part

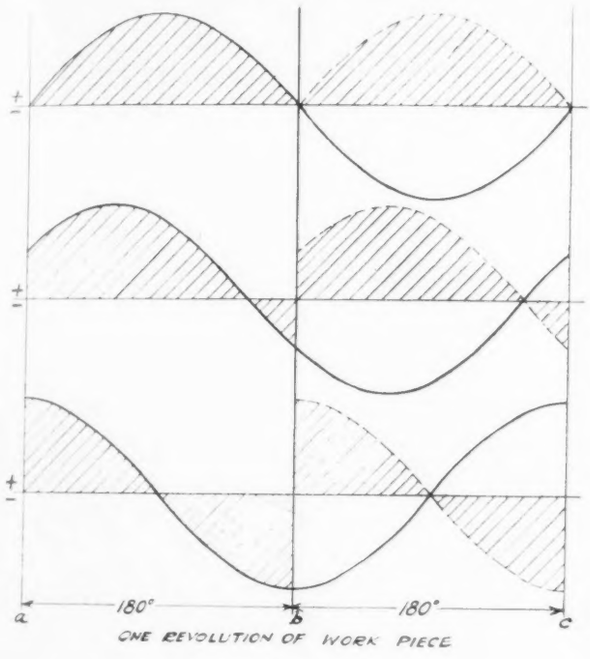

Fig. 13

depending upon whether the switch on the control panel is turned to "remove front" or "add front." The setting of this switch is determined by the method of correction to be used.

The functioning of the commutator will perhaps be best understood by referring to Fig. 13. The solid-line sinusoidal curves represent the output of the pickup coils. If we assume that the commutator is set so that the contact change takes place at *a*, *b*, *c*, etc., these points would be where the curve crosses the axis in the upper diagram. For such a setting the direct contacts are closed from *a* to *b* and the reverse contacts are opened for the same period. From *b* to *c* the direct contacts are open and the reverse contacts closed. Hence for this setting, the indicating instrument, which is a d-c. microammeter, receives two direct-current impulses for every revolution from *a* to *c* and will show a maximum reading for this particular setting.

If we shift the commutator slightly, as shown by the second diagram, the microammeter will receive for every revolution two direct-current impulses equivalent to the positive shaded areas minus the negative shaded areas. Consequently the microammeter reading will depend upon how far the commutator has been shifted.

If the commutator is shifted 90° from the position for maximum readings, as shown by the third sketch, the positive and negative areas are equal, resulting in a zero reading. It is with the commutator in this position—the most sensitive—that we take the angle of the unbalance. The microammeter thus serves as a null-point indicator.

(Continued on Page 390)

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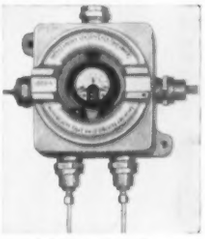

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Vol. I, No. 4 GUEST EDITOR: C. S. GOOCH September 1942

Need of Complete Instrument Service Manuals

An Editorial by **C. S. GOOCH,** *Guest Editor*

Instrument Department, Shelby County School of Aeronautics
Whitehaven, Tennessee

THE enormous number of new types and designs of aviation instruments introduced in the last few years, and the fact that ship manufacturers and operators have so far failed to agree on standard instrument panel layout, or even as to which instruments are essential and which merely desirable when space permits, makes the job of the aircraft instrument technician vastly more complicated today.

A decade ago, instrument men in the aviation field were expected to know and understand five or six fundamental types of instruments and possibly minor variations of these due to differences in manufacturing technique, which were few because of the small number of manufacturers engaged in this kind of production. Materials were easily recognized, methods of adjustment were more or less standard, so that the average aircraft instrument mechanic could open and repair the majority of instruments with experience on only one of each type.

All this leads up to the fact that the craft has undergone a metamorphosis. Modern improvements have made old practice obsolete. The changes in materials, design, methods of construction, and refinements in manufacture have had a far-reaching effect on repair methods. Hundreds of new types of instruments, some designed to do the old job in a better fashion, and some conceived for new and additional requirements brought about by increased speed and efficiency of the modern aircraft, all have contributed to make the field a much larger and more scientific work, and one calling for more than casual familiarity with nearly all of the pure sciences. While aviation in general was making progress, the aircraft power-plant engineers were advancing apace, so that the present-day engine is a monument to precision by comparison with the engine of only ten years ago. Such changes in engine detail called upon the instrument designers for more complicated and new measuring devices.

C. S. Gooch (the C. S. stands for Cornelius Skinner) is a native of Kentucky, a Texan by adoption or by virtue of a twenty-five year visit, and a Tennessean for reasons now covering most of our activities—the war. Graduated in 1927 from the University of the South, at Sewanee, Tennessee, with what he describes as "moderate scholastic honors" including the editorship of the college annual, he began a career in the radio field shortly thereafter, including—in succession—radio servicing, sales, broadcasting, with side ventures into the refrigeration, air-conditioning, heating and ventilating fields. In 1939, having disposed of his broadcasting interests, he became interested in aviation, and the technicalities of aircraft instruments in particular. A study of this field disclosed that it included all the fascinating aspects of radio, plus an abundance of new material to hold the interest of an inquiring mind. He accepted a position in the maintenance base of Braniff Airways in Dallas, Texas, and devoted his spare time to studies in aeronautics, airplane engines, aircraft construction, and especially airplane instruments. Shortly after Pearl Harbor, the Shelby County School of Aeronautics was faced with the problem of expanding its defense training school, which had functioned as one of the outstanding defense units since early 1939, but with a smaller crew of instructors. Mr. Gooch was invited by chief instructor Brant Conway to become an instructor in the instrument department; and accepted. Mr. Gooch is now 37, has a firm determination to stay in the aircraft field, but refuses to predict the future of aviation after the war is won. For the present (and this applies to any of us) he is standing on the job where he feels he can de the most good for an early victory.

Add to the above, the fact that many new names are appearing in the list of those manufacturing instruments for the aviation trade. Names old in instrumentation, but new to the aircraft industry, are making a place for themselves beside those which have been so long identified with aviation that they have become synonyms for certain specific types of instruments. Each of these new manufacturers has new ideas in materials. Each has innovations and possibly improvements to incorporate in the design or method of construction formerly considered standard. The craft is receiving a blood-transfusion which will inevitably lead to vigorous health. In the meantime the individuals presently engaged in the business of maintaining and repairing aircraft instruments are faced with a serious problem.

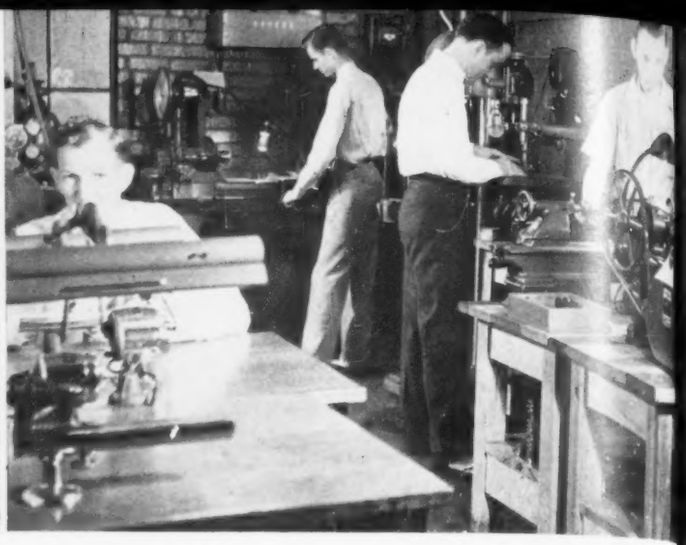
The plurality of types and designs has so complicated the work and required knowledge of the maintenance man that he finds the number of hours in the day too few even to keep up with newly announced models. Information as supplied willingly by some manufacturers and grudgingly by others is such as furnished by motorcar manufacturers to prospective owners, which always included the familiar words "for further adjustment see your dealer."

Designers marketing unpatented or unpatentable devices are justified in withholding technical information from the public. The remarks are not intended as a slur on the manufacturers. The fact remains that the condition can have chaotic results.

One solution is specialization. Novices in the instrument field can be trained in a short time to understand and repair a few types of a small bracket of the long list of instruments. This method seems to be successful with repair depots handling a large volume of work. But this solution does not serve the needs of the operator flying fewer ships;

(Continued on page 374)

One of the night classes in session in the instrument classroom at Shelby County School.



Part of the machine shop conducted in connection with the Instrument Department.

Six-month Intensive Course Trains Civilians in Army & Navy Aircraft Instrument Repair

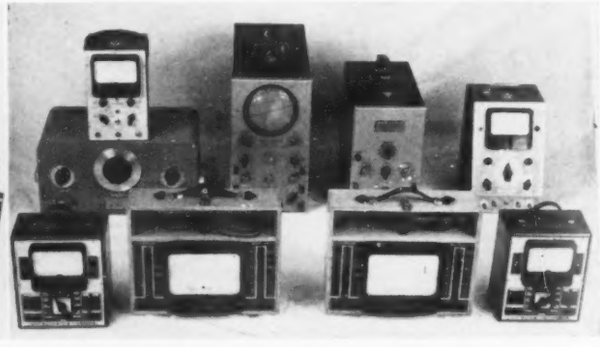
LOCATED at Whitehaven, near Memphis, Tennessee, the Shelby County School of Aeronautics is one of the larger defense schools turning out trained mechanics for work in maintenance bases of the armed forces. All of the enrolled students are civilians, most of whom have had previous mechanical experience in other fields. After a visit to the school, Dr. J. Chester Swanson, senior educationalist of the Office of Education in Washington, said the training at Whitehaven is receiving national recognition.

"They have been doing very good work along the lines of aircraft maintenance and repair, but particularly in the field of aircraft instruments," said Dr. Swanson.*

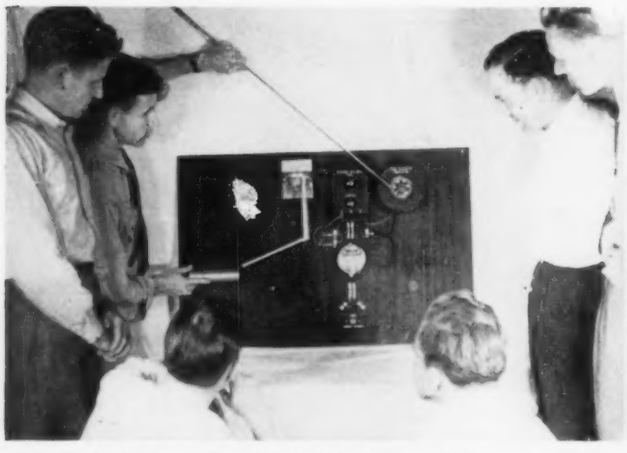
*Quoted from the *Commercial Appeal*, Memphis, Tenn.

The instrument department of the S.C.S.A., under the direction of Brant B. Conway, chief instructor, includes instructors Arthur E. Berg, C. S. Gooch, and Almon C. Emery —all former air-line instrument maintenance men—and Alan Williams, former A and E mechanic for Curtiss Wright. With provision for one hundred and forty trainees, lavish equipment as shown in the accompanying photographs, and a plentiful supply of instruments of all types, each student receives in six months' time a thorough ground work in both theory and practice of instrument maintenance. Much of the equipment shown was designed and built by the staff of instructors. The larger pieces were built by other departments of the school under the direction of the

Electrical standards used in calibrating aircraft instruments at the Shelby County School.

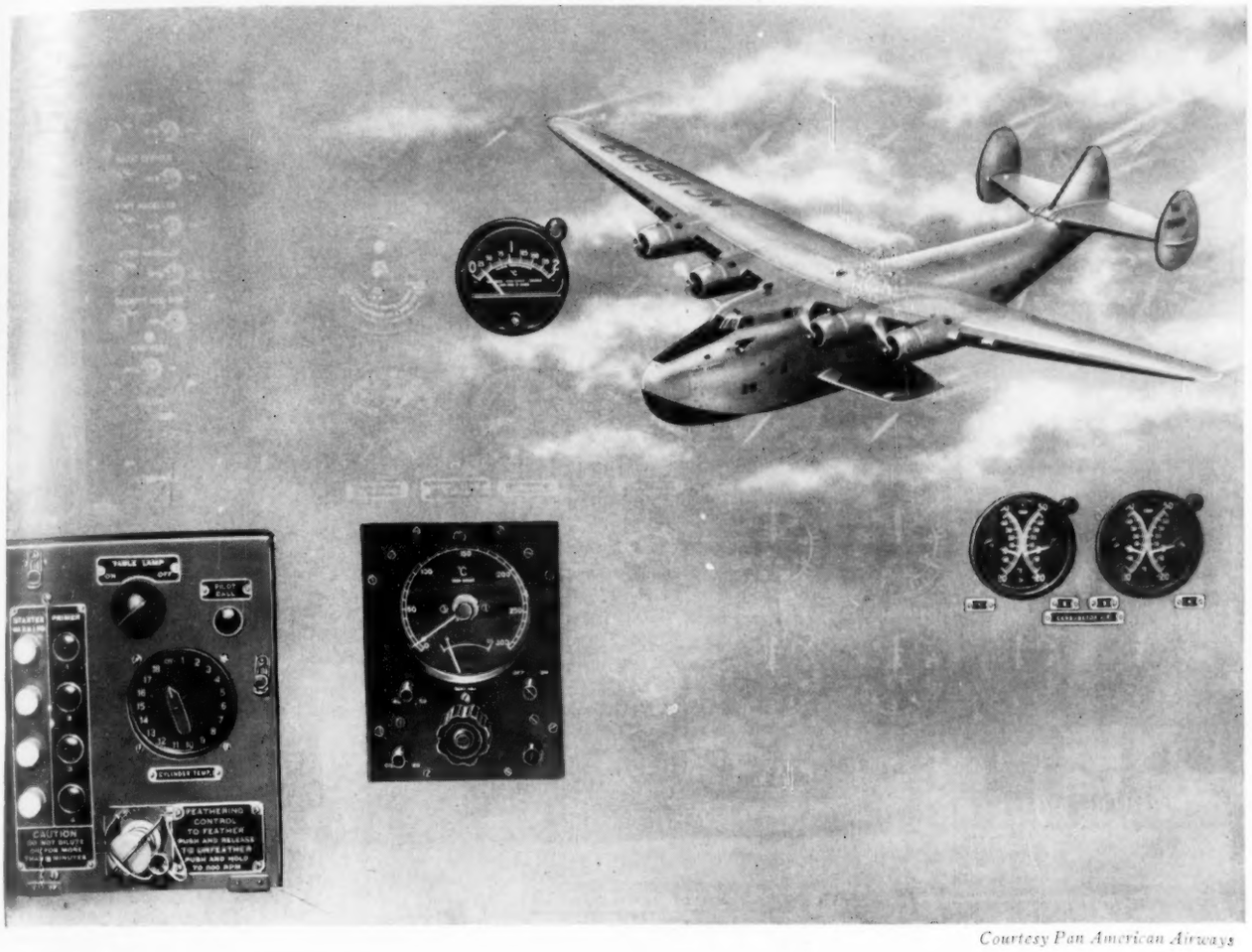


Part of the measuring equipment. Students are instructed in the use of all of these laboratory instruments.



Instructor A. C. Emery demonstrating Liquidometer fuel quantity system.

Part of equipment for testing and calibrating gyroscopic instruments.



Courtesy Pan American Airways

Uncle Sam and "Pan Am"

Place Stamp of Approval on Lewis Instruments

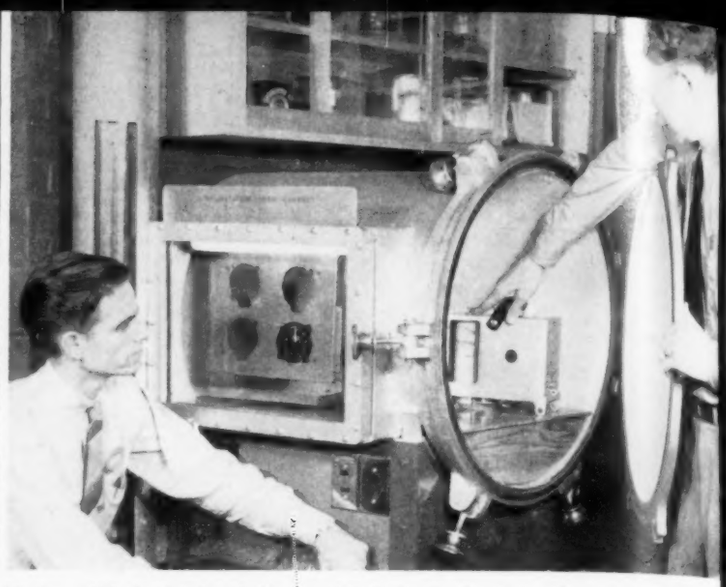
Lewis engine instruments on Pan American Airways great Flying Clipper Ships and on many military aircraft have earned the stamp of approval from both "Uncle Sam and 'Pan Am'."

The engine instrument panel of Pan American's Yankee Clipper, shown above, highlights several Lewis instruments doing their part of the job. The instrument at the upper left indicates the temperature of the glycol used in the cabin heating system. The selector switch at the lower left operates the pyrometer potentiometer (next right) which gives engine base and cylinder head temperature readings on each of the four engines. At the extreme right are two Lewis dual carburetor temperature indicators. Technical data on these, and other Lewis instruments are given in the Lewis aircraft instrument catalog.

THE LEWIS ENGINEERING CO.

NAUGATUCK, CONNECTICUT

C. S. Gooch, demonstrating position indicator system. (Bomb shackle in background.)



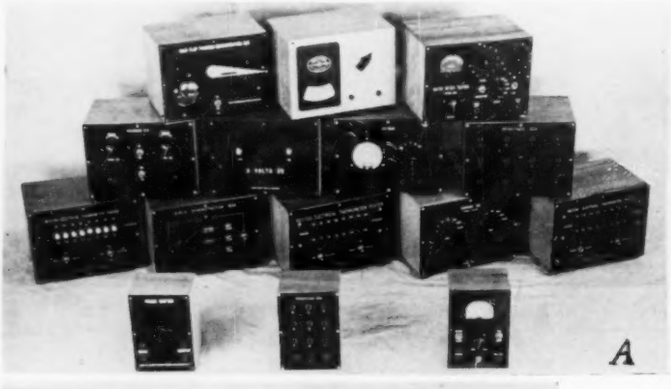
Altitude chamber designed and built by the Instrument Department. (Instructor Gooch and student.)

instrument staff. The greater portion of the calibration equipment is factory made, and in many instances exact duplicates of the high-standard tools used by the Army and the Navy.

In dust-free air-conditioned rooms, each student has his own watchmaker's bench, compressed air gun, fluorescent light, hand tools, and minor equipment. Sufficient stocks of materials, large tools, and specialized equipment are available to students from an adjoining tool-room. Calibration equipment is located within the classroom, as well as such shop equipment as lathes, drill presses, shapers, grinders, power saws, paint spray booths, welding and soldering torches. Instruction in the manipulation of all the above is included in the course. Facilities are arranged to make it possible for each student to be advanced as rapidly as the training can be absorbed.

Proceeding on the idea that men cannot be taught to repair instruments intelligently until they are first taught the fundamentals, Mr. Conway and his associates have devised a unique method of selection and an unusually broad curriculum. Before a prospective student enters the instrument classes, he is given several tests for the dual purpose of determining his aptitude for this type of work and his ability to keep up with the average learner. Manual dexterity tests determine applicants' ability to use hands and small tools. Problem tests give an indication of powers of observation and accurate thinking. Included in these tests, but carefully concealed, are factors to check on how much previous training, knowledge, or experience has stuck in the mind of the student. Although the tests are simple and easy to give or take, the grades invariably coincide with and predict the rate of progress as training advances.

After selection, each student is assigned to a session of the twenty-four hour schedule where he will be supervised



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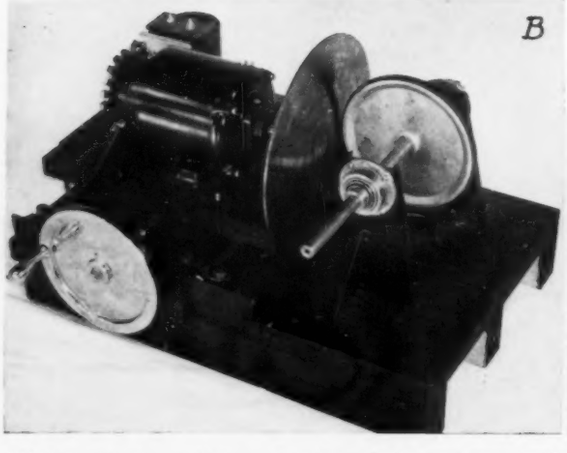

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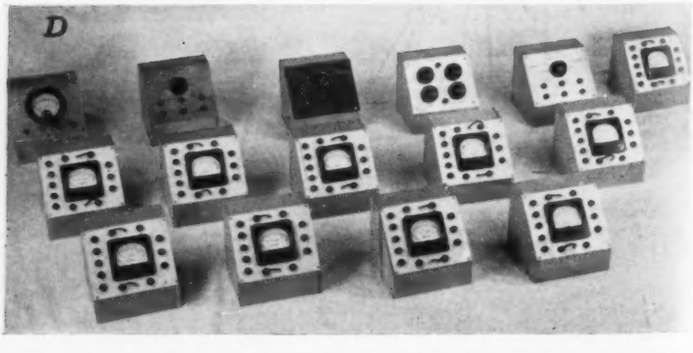


D

(A) Demonstration equipment and test boxes built by students. (B) Tachometer calibrator drive designed and constructed by Instructor Arthur Berg.

(C) Fuel analyzer indicator, showing method of replacing case with pyralin to make mechanism visible. (D) Volt-ohm-milliammeters built by students

Nerve Center

Through this one Cannon Plug pass the most important engine circuits on many fighting planes

This Cannon Type AN Connector is often used as the master engine "disconnect." It carries fifteen circuits from eleven different types of engine controls and instrument transmitters to the pilot's controls and indicators.

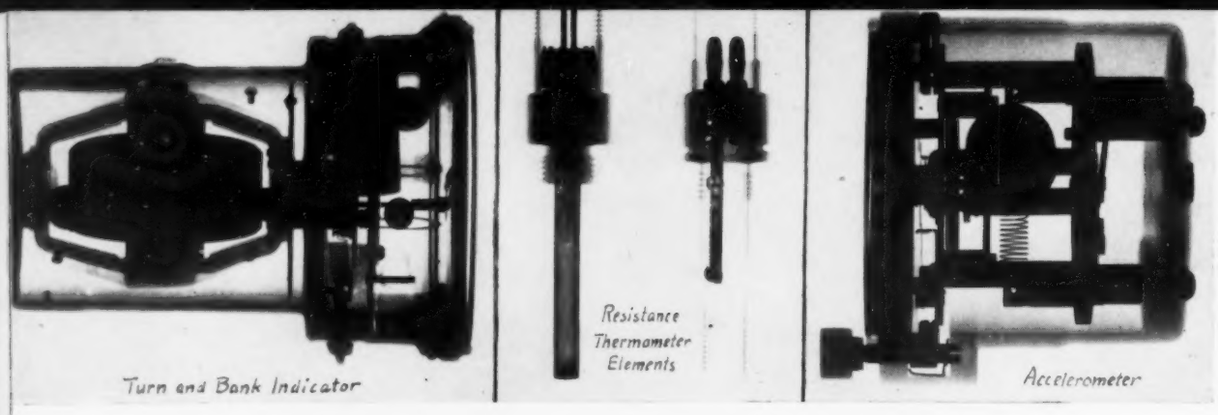
With this precision-built connector the maze of vital electrical circuits for the power plant can be carried with absolute security...yet all of these circuits can be broken instantly for routine service or major engine overhauls.

Cannon pioneered in the aircraft field with the types AF, FM and K Connectors which are used throughout the world on all types of planes. Twenty-seven years of Cannon specialty manufacture in the electrical field has made Cannon's interpretation of the AN specification an outstanding product for America's fighting planes.

Cannon Connectors of various types have become standard equipment for aircraft instruments and accessories as well as for the wiring systems of the planes themselves. They are also used in countless fields where electrical connections must be made quickly and with positive security.

CANNON

CANNON ELECTRIC
DEVELOPMENT COMPANY
LOS ANGELES, CALIFORNIA



X-ray shadowgraphs of aircraft instruments. Shelby County School of Aeronautics.

and taught by at least two of the staff of five instructors. He receives an identification badge, tool checks, and preliminary instruction in drawing tools from the tool room, writing requisitions for materials, classroom decorum and regulations. Classes meet for six-hour periods. Each student is responsible for the appearance and condition of his own workbench, and the care of tools issued to him. Tools are inspected by tool-room assistants each day at the end of the session.

Preliminary instruction begins with nomenclature, screw sizes, threads, materials and measurement with micrometer and calipers. Following this, the uses of hand tools and simple machine tools are taught. During the first few weeks, trainees are allowed to disassemble and clean simple gages, and reassemble and calibrate them. As each new instrument is introduced, instruction on the calibrating equipment is given, sometimes to one individual student, but more often to a group of three or four. No student is allowed to use any of the calibration equipment or machine tools until thoroughly instructed in its principles and operation. During the time this preliminary instruction is going on, the student is beginning work on his notebook, which will eventually contain more than a hundred sketches and information on every type of aircraft instrument. Each day a separate instrument is drawn on the blackboards, and a written summary of its purposes and uses, tolerances, methods of calibrating and tools required to disassemble and reassemble, attached.

A course on fundamental electricity is repeated over periods of about one hundred days, so that each student receives thorough grounding for future work on electrical instruments. Basic physics is taught simultaneously by rotating the divisions of light, heat, sound and matter.

Due to the variety of instruments now in use, and the demand for specialists, the men in training are urged to select a field and concentrate on gaining experience in one particular branch, as their training progresses. Gyro men are selected on a basis of previous care in early work on simple instruments, and allowed to spend their last two months on gyro work. Men with electrical aptitude are given electrical instruments exclusively during the final weeks of training, so that they may gain as much experience as possible before going into civilian work at one of the Army bases. Others show more inclination for the diaphragm instruments, such as altimeters, airspeed indicators, rate of climb, and similar types. After completion of the course, all men trained are generally familiar with all aircraft instruments and thoroughly familiar with those instruments included in their chosen branch of the field.

After the war, what becomes of these men trained at enormous expense in such a highly specialized craft? Many will return to previous occupations—selling, servicing, manufacturing, a variety of articles not essential to war-time economics. A large portion will stay in the aircraft field, to maintain the great fleets of air transport ships promised by the prophets of the day. A few will become the aircraft instrument "big-shots" of the next generation, and possibly there are one or more among them who will become the Henry Fords of aviation. For the present, students and instructors alike have one thing in mind: "There is no business in America today other than that of winning the war."

Statistical Predictions

By COLE WORSHAM

{Cole Worsham is employed as senior instrument mechanic at Braniff Airways, and normally stationed at the Dallas base, but at present is loaned to the "Air Service Command" and located in Brownsville, Texas.
—C. S. Gooch}

THE figure of 125,000 airplanes set by President Roosevelt in his fireside chat has been accepted by the citizenry as the completed size of our armed airforce by the end of next year. Reports from the factories and enthusiasm from production heads indicate that the goal will probably be exceeded. Let us examine this figure with particular reference to aircraft instruments.

Assuming a spread from the smallest trainer utilizing some eleven to twenty instruments, to the largest bomber requiring seventy to one hundred instruments, will give us an average instrument panel of fifty units. This is on the conservative side, the probable average being higher. Simple arithmetic gives the astounding total of 6,250,000 instruments.

To get a basis for comparison, let us consider the nation's peace-time airline fleet of some 375 planes. These ships carry an average of forty-five instruments each, or a total of 25,875. The average flying time for passenger airliners is ten hours per day. To maintain these 25,875 instruments requires the full-time effort of approximately 800 instrument specialists employed by the airlines.

In addition there is a quantity of repair service such as was done by the factories in the past but no longer, because the factories now find themselves hard-pressed to produce the necessary new instruments and are unable to give the required attention to work sent in from the field for service.

If we assume that military ships will fly ten hours per day (equalling the flying time of airliners) and if we calculate the maintenance personnel on the same basis, we arrive at the figure of 250,000: *a quarter of a million instrument men for the Armed Forces.*

Of course it is impossible to compare war-time maintenance with peace-time methods. Maintenance is defined as "the keeping of equipment in a continual state of efficiency." The word efficiency means just as much to the Army and the Navy as it does to the airlines, but common-sense tells us that such an army of technical men is neither practical nor available. Several facts enter the picture to diminish the figures above.

Most of the air armada will be new. Instrument equipment being new will be good for 1000 to 3000 hours before overhaul is required, except for occasional defective units requiring attention before their normal life expectancy. Combat conditions sometimes place exigency above efficiency. A ship on a bombing mission will not stop at an intermediate station to replace a few instruments whose log-time has almost expired. Crack-ups cause the retirement of many instruments after only a few hours of useful life; and ships lost in battle are undoubtedly charged off as "irreparable."

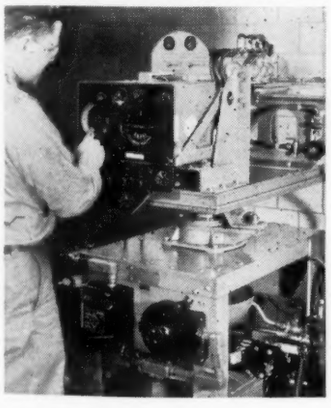
Experience in the last war taught us that great stockpiles of reparable equipment accumulate during the fighting, because the time element makes it necessary to substitute new matériel to replace worn or damaged equipment.

This points out an important thought for men engaged in

The **Aircraft Instrument Technician** *Can Train His Sights on* **2 Objectives: VICTORY TODAY ...SECURITY TOMORROW**

Many graduates of other instrument courses come to C. S. A. I. for advanced training on Directional Gyros, Artificial Horizons, and the Automatic Pilot.

Testing Sperry Automatic Pilot on a Scorsby Unit



If you are looking for a way to do your part in our Victory program... if you're wanting a secure future for yourself... investigate the opportunities that await the aircraft instrument technician.

In Army and Navy air forces, at air bases and repair depots throughout the world, in aircraft factories, in instrument manufacturing plants, with the Civil Service, with the airlines and commercial air freight lines ... wherever planes are based, you'll find instrument technicians occupying key positions.

The Chicago School of Aircraft Instruments is the largest, best equipped school in America ... devoted exclusively to basic and advanced aircraft instrument training. In fact, it is one of the few schools equipped with Scorsby Test Units and Automatic Pilot installations for complete gyroscopic instrument training. This training is included in the C. S. A. I. Master Course requiring only 28 weeks to complete. Graduates of this course which covers general, electrical and gyroscopic instruments are eligible for Civil Service appointments without further experience or examination.

The school has been commissioned by the U. S. Army Air Forces to train enlisted men as instrument technicians. Civil Aeronautics Administration has awarded the school its repair station rating ... your assurance of qualified, recognized training so important to your success in this highly specialized field. Let C. S. A. I. train you for an essential place in our war program ... for a high pay future in America's greatest industry. Write for illustrated booklet showing present day and future opportunities in this fascinating field.

Get This Free Booklet

It gives you the complete story of this new and vital branch of Aviation ...shows you the opportunities that await the instrument technician.

Chicago **SCHOOL OF AIRCRAFT INSTRUMENTS**

2200 Lawrence Avenue, Dept. N-9, Chicago, Illinois

the instrument profession. For many years after the war is won, there will be work to be done, overhauling, repairing, and certifying the instruments removed from military ships during the war, and reconditioning such equipment for restoration to service, where it will gradually be absorbed by the normal retirement of worn-out and out-moded instruments.

Instrument Overhaul Charges

By RAY SNYDER, President Snyder Aircraft Corp. (Aircraft Supplies & Service), Chicago, Ill.

THE overhauling of Aircraft Instruments, both mechanical and electrical, requires precision test equipment, an adequate supply of properly stored replacement parts, and skilled operators. Each contributes to the overhaul cost, which is generally covered by a flat rate charge throughout the country.

On the flat rate charges, labor only is taken into consideration and replacement parts and the refinishing of dials and pointers are extra. The variation in parts is from approximately a dozen units in an oil pressure gage to 100 or more in a Sperry Directional Gyro.

Current flat rate charges for the overhaul of standard aircraft instruments are as follows:

Airspeed Indicators	$ 6.00		
Altimeters	from 6.00	to	$20.00
Compasses	8.25		
Clocks	6.50		
Gages	from 2.00	to	6.00
Rate of Climb Indicators	from 10.00	to	15.00
Tachometers	from 5.50	to	10.00
Turn and Bank Indicators	15.00		
Directional Gyro	47.00		
Gyro-Horizon	47.00		
Electrical Instruments	from 8.00	to	10.00

Selection and Proper Use of Cleansing Materials for Aircraft Instruments

PLAIN UN-LEADED GASOLINE is the cleaning agent most widely used, and the one which is best for most purposes. It is sold by many refiners under various trade names. It will suffice for the average cleaning job, having the advantage of freedom from moisture, quick evaporation, good penetration qualities, and an affinity for grease. Gasoline has the disadvantage of being ineffective on corrosion and stains.

Carbon tetrachloride will dissolve many forms of corrosion immune to the action of gasoline, but has the disadvantage that it leaves a film whenever any stain has been dissolved during the process of cleaning. This requires an additional bath with fresh carbon tetrachloride, after cleaning is finished. Ferrous parts washed with carbon-tet are highly susceptible to rust, a problem which does not arise when using gasoline.

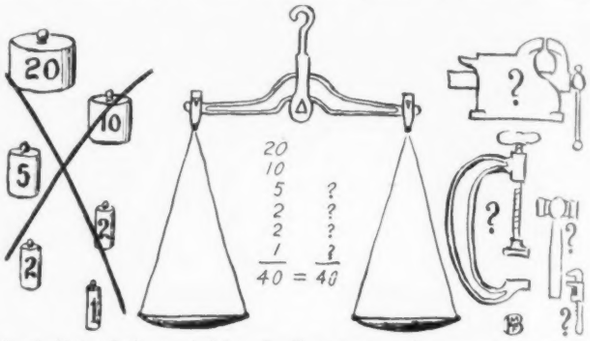
For removing corrosion or stain from most instrument mechanisms, a solution of liquid soap and aqueous ammonia, such as used in watch cleaning machines, is very satisfactory. Proportions are one part aqueous ammonia, one part liquid soap, and two parts water.

Instrument mechanisms can be immersed bodily in this solution, after removal from the case. Some means of working the moving parts of the unit is desirable to insure penetration of the solution to all crevices. In the case of airspeed indicators, altimeters, climb indicators, etc., this working can be accomplished by placing under a bell jar and alternately applying suction and releasing it. The solution will clean brass parts to a beautiful lustre, and steel parts show marked improvement in appearance after a few minutes' immersion. To prevent staining, the solution must be removed immediately after the mechanism is withdrawn from the cleaner. Common practice is to dip immediately into a rinsing jar filled with gasoline, and then into a third jar full of clean gasoline, after which the assembly is dried with a small stream of air. If the above procedure is carefully followed, thorough cleaning will be the result without complete disassembly.

On badly stained assemblies, the washing action of the soap solution can be assisted by using a small soft lettering brush, and scrubbing the corroded parts gently. Hair springs are not damaged by the solution. It should not be allowed to enter the inside of diaphragm capsules, because of the difficulty in rinsing such places.

BRAIN TWISTER

EXCESS LOAD was worrying the boys of the 7777th Bombardment Group Flying Repair Shop as they prepared to take off for Egypt or Australia or Shangrila. And the excess load was—weights! They had a portable equal-beam scale and the usual set of six weights for weighing in even pounds up to 40 lbs. (See picture.) But the final



check-list of the weights of all crew members and all equipment showed an excess of just 40 lbs. over the permissible take-off load of the Flying Shop. If the set of weights were left behind, the scale might as well be left behind, too. And there was no time to buy or borrow a spring scale.

Professor Einstein, who had come to wish "happy landings" to the Lieutenant, pointed out that the set of six weights *could* be left behind; and that the scale *could* nevertheless be used to weigh *any amount in even pounds* from 1 lb. to 40 lbs.

"I see by your check-list that FOUR items of your Flying Shop equipment will do the trick," said the famous mathematician. "They are this vise, this clamp, this hammer and this wrench."

The lieutenant and his men couldn't believe it. They made a few quick mental additions and then told Einstein that the possible combinations did not include all even weights from one to forty.

"Don't forget you're taking along *equal-beam* scales!" said the great A.E., thereby giving the clue which will permit *Instruments* readers to determine the four weights.

What are the four weights? (Answer on page 350.)

Need of Complete Instrument Service Manuals

(Continued from page 367)

for example an air freight line using ten cargo planes, roughly three to four hundred instrument overhauls per year. An instrument technician specialized on only part of the instruments would be worthless to such an operator. The individuals in such an instrument department would be required to maintain *all* of the instruments used on *all* of the ships operated.

This situation had its counterpart in the radio industry during the first years of broadcasting. Manufacturers were producing masterpieces of engineering skill, only to find them falling into disrepute with the public because of lack of technical information among the service men who were supposed to keep them operating. That situation was not rectified until these manufacturers were convinced that broadcasting such information was good business. The defect was eliminated when publishers were allowed to print and sell "service manuals" containing all information necessary to repair and test such equipment with intelligence. A set of these "manuals" for aircraft instruments would fill several volumes today, and many more in the years to come, but would be a tremendous contribution to the future of aviation.

REMOTE CONTROL

Sperry's
HYDRAULIC
"EXACTOR CONTROL"

assures
the smallest movement being
transmitted over long distances
without backlash
Installation simple, quick, economical

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SINGLE TUBE REPLACES:
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TRANSMITTER

Standard on U. S. Army Air Corps Test Stands

SPERRY PRODUCTS, INC.
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METALLIC BELLOWS
EXTRUDED TUBING

We manufacture HYDRON bellows and bellows assemblies ready for installation in steam traps, relief valves, temperature regulators, pressure regulators, air valves, and automatic temperature and pressure controls, including aircraft engine cooling systems, carburetors, and super-chargers. We also manufacture HYDRON extruded tubing for aircraft prestone radiators, oil coolers, inter-coolers, and after-coolers, for liquid-cooled and air-cooled motors.

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CHICAGO **564 E. FIRST ST., BOSTON** **DETROIT**

84 years

experience in the design and manufacture of special instruments is the background for Barbour Stockwell Tachometer equipment installations on Pan American Clipper ships.

Information on special facilities available on request.

BARBOUR STOCKWELL CO.

RELIANCE Tachometers, Panels, Revolution Counters, Motion Recording and Special Instruments

205 BROADWAY CAMBRIDGE, MASS.

Timers

A line of QUALITY

Interval Timers
Running Time Meters
Reset Timers
Time Delay Relays
Cycle Timers
Repeat Cycle Timers
Time Switches
Signal Control Switch
Multi-Contact Timers
Impulse Timers
Special Timers

Designed and built for accuracy—long life and freedom from trouble.

☆

Write us of Your Needs and Problems.

by

Cramer

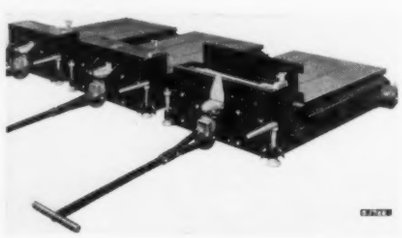
The R.W. CRAMER COMPANY, Inc.
CENTERBROOK CONNECTICUT

The Month's NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions. When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

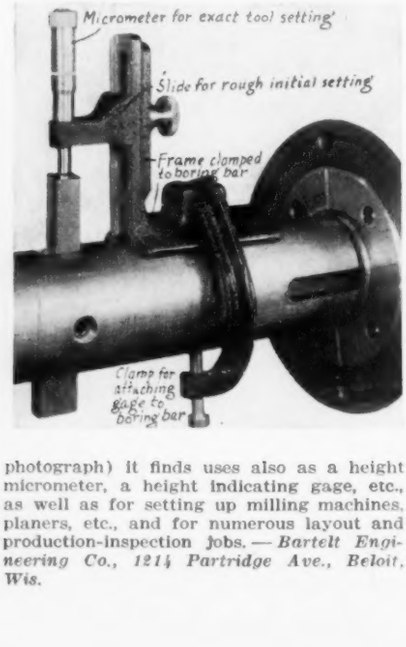
Airplane Weighing Scales

New "Model 9798 Airplane Weighing Scales" may be used to weigh the landing-wheel and tail-wheel (or nose wheel) loads, to determine total weight and to determine distribution of loading. Illustration shows a battery of three scales for determining total weight. Platform height is 9½"; capacity is 10,000 lbs. with 1-lb. graduations. Top-reading indication is a convenient design feature.—*Toledo Scale Co., Toledo, Ohio.*



Multi-purpose Shop Gage

New "Bartelt Tool Setting Gauge" consists of an L-shaped frame with several accurately-finished surfaces, a slide and a micrometer head (or dial indicator). While it was primarily designed for setting of cutting tools in boring bars (see annotated photograph) it finds uses also as a height micrometer, a height indicating gage, etc., as well as for setting up milling machines, planers, etc., and for numerous layout and production-inspection jobs.—*Bartelt Engineering Co., 1214 Partridge Ave., Beloit, Wis.*

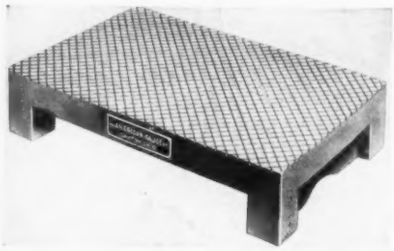

Micrometer for exact tool setting
Slide for rough initial setting
Frame clamped to boring bar
Clamp for attaching gage to boring bar

Dimness-controlled Signal Lights

New "Dim-E-Roid" panel and signal lamp obviates need of incorporating transformers and resistors in electrical systems for dimming intensity of signal lights. Polaroid disks or a mechanical shutter control light intensity without interference with the electrical circuit proper. Made entirely of non-ferrous metals, "Dim-E-Roid" utilizes a plastic jewel in any color desired for differential signal purposes. Two models: "Model 1920" has mechanical shutter, can be adjusted from a total blackout to full intensity. "Model 1874" uses opposed Polaroid disks. Both are identical in mounting dimensions. A slight turn of head varies light intensity. "Dim-E-Roid" has been accepted for use in instrument panels of military aircraft for signal purposes.—*American Radio Hardware Co., Inc., 476 Broadway, New York City.*

Precision Lapping Plate

Improved type of lapping plate is 8" wide by 12½" long and 2½" high. Cast-iron block "of especially fine grain," about 1⅛" thick, mounted on four legs; surface cut with 1/16" grooves in ¼" squares at 45° to sides of plate. This gives grooves a superior cutting action. Plate surface is first ground and then lapped until accurately flat; and grooves are cut deep so that surplus lapping compound will not accumulate on surface. This Lapping Plate is highly recommended for all types of gages and surfaces requiring close tolerances. Prompt deliveries based on reasonable preference ratings.—*The American Gauge Company, 128 Bayard St., Dayton, Ohio.*

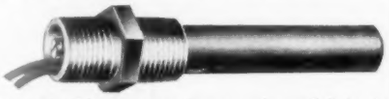


Temperature Controller

New model of "Remote Bulb Microtherm" for control of temperatures in ducts, tanks, ovens, dryers, cooking kettles, etc., is announced. For illustrated description of previous model see *Instruments*, Nov. 1940, page 326. New model differs only in tubing style.—*Barber-Colman Co., Rockford, Ill.*

Coupling Head "Thermoswitch"

New Coupling Head "Thermoswitch" is designed for insertion into a closed liquid or gas system by means of a ½" standard pipe thread. As the shell is brass it should be used only where the medium in contact is not corrosive. Feature of design is facility



for attaching many types of condulets to head, such as waterproof or explosion-proof fittings. See *Instruments*, July 1938, page 176, for initial announcement with diagram and technical description of "Thermoswitch" principle. Available as regular (R) when the contacts open on an increase in temperature; inverse (I) when the contacts open on a decrease in temperature. Adjustable operating range is -50 to 400°F. (to 600°F. special). Contacts rating 10 amps, 115 volts; 5 amps, 230 volts, a-c. Also 25-amp. capacity (¾" I.P.S.) special model.—*Fenwal Inc., Ashland, Mass.*

High-vacuum Gage

New "Type HG-200 Ionization Gauge Meter," designed to operate in conjunction with maker's "Type VG-1 Ionization Gauge," provides a method of measuring pressures from 10^{-3} to 10^{-9} mm. of mercury. Its cir-

cuit features a stabilized amplifier in a balanced vacuum tube of voltmeter design with negative feedback, and an integral amplifier recalibration for elimination of amplifier variation. Other variations in performance are prevented by gas tube voltage regulation and automatic grid current control. *Operation:*—A switch is thrown to degas grid of ionization tube, while circuit amplification is set to a standard value on the single indicator and grid current is set to correct value where the circuit will hold it constant. Plate current can then be read directly from the indicator and converted to pressure readings with the ionization tube factor. "Type VG-1 Ionization Gauge," used in this arrangement, has a high sensitivity of 200 microamps. per micron. Unit comes complete with all necessary cords and plugs and ionization tube ready to seal onto any Pyrex system; operates on any 110-115-volt, 60-cycle line.—*Distillation Products, Inc., 755 Ridge Road West, Rochester, N. Y.*

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We suggest the Jones Heavy Duty Hand Tachometer for indicating rpm and surface speeds of all types of machinery in which the moving parts are readily accessible.* It is built to "stand the gaff" and maintain accuracy in hard, everyday service. Single and triple range models up to 12,000 rpm. Instruments are furnished complete with carrying case, including extra tips. Rubber-tired wheel for measuring surface speeds available at slight additional cost.

Write for new descriptive Bulletin 1710-I

*Where moving parts are not readily accessible, as in turbines, centrifugal pumps and other totally enclosed machines, and also for measuring vibrations per minute, we recommend our Frahm Vibrating-Reed Tachometers. Ask for Bulletin 1590-I.

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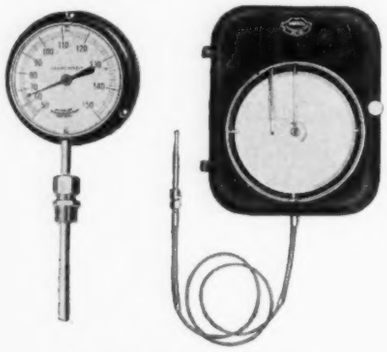
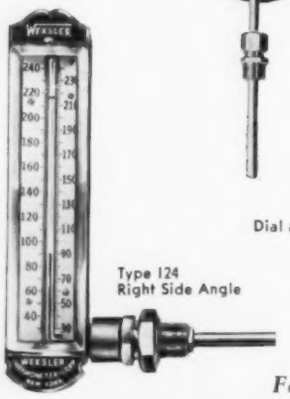
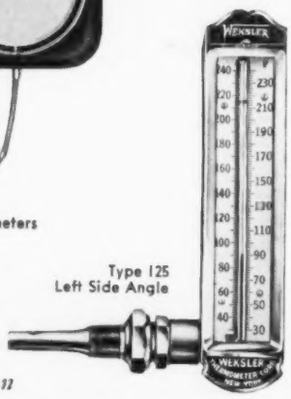


Dial and Recording Thermometers



Type 124 Right Side Angle



Type 125 Left Side Angle

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- Table Rotary Drive Rheostats.
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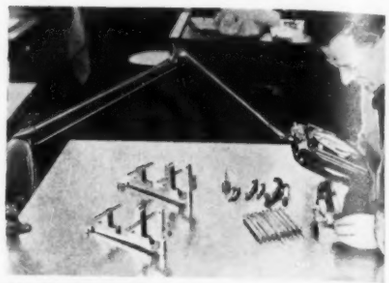
- Adjustable Resistors.

PROMPT DELIVERY

Illuminated Magnifiers

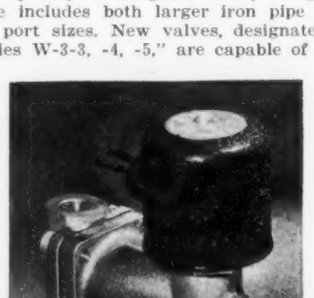
Four new models of "Super Sight" adapted to close inspection, small parts assembly, instrument adjustment and precision machining are announced: "No. 95ZC" for inspection work has two magnifying lenses



(top lens 5", lower lens 4"), lower lens adjustable to proper focus; lenses lighted separately to permit using one or both lenses as occasion demands. Head is balanced to bracket and can be instantly put in any position over a wide bench area. "No. 89ZC" (upper illustration) has one magnifying lens (5" diameter); head balanced to bracket enabling its use over a wide bench area. For inspection, small parts assembly and bench work. "No. 89U" for precision machining has one magnifying lens (5" dia.); fitted with safety lens to protect magnifying lens when required. Equipped with universal brackets (T-slot or G.S.114). "No. 44ZC" (lower illustration) has one magnifying lens (4" diameter); head balanced to bracket and can be used in any position over a wide bench area. For bench work and small parts assembly. — *The Boyer-Campbell Co., 6540 Antoine St., Detroit, Mich.*

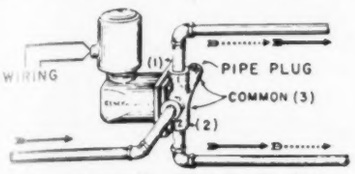
Three-way Magnetic Valves

Completely redesigned 3-way magnetic valve includes both larger iron pipe sizes and port sizes. New valves, designated as "Series W-3-3, -4, -5," are capable of han-



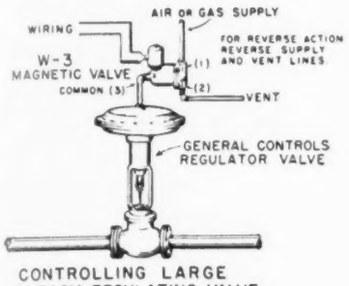
dling oil, water, air, gas, steam, refrigerants and similar fluids and vapors not corrosive to valve material up to 400°F., with I. P. S. sizes up to 1" and port sizes to 15/32". Three-way valves are suitable for control of fluids to piston and diaphragm operators on valves, dampers, etc., as well as for applications where fluids must be distributed from a common source, for pneu-

matic pumping or for selection of fluid sources. Being of single magnetic type, valve cannot assume an intermediate position, i.e., when port 1 is open to the flow, port 2 is closed when current is on; when current is off, port 2 is open to flow and port 1 is closed. If reverse action is desired



DISTRIBUTING FLUID FLOW

APPLICATIONS:



CONTROLLING LARGE DIAPHRAGM REGULATING VALVE

it is only necessary to change No. 1 and No. 2 connections. New design also permits high-pressure connection to either common, No. 1 or No. 2 ports without affecting valve operation as long as pressures (differential) are held within certain ratings. Available for all commercial a-c. or d-c. voltages.—*General Controls Co., 801 Allen Ave., Glendale, Calif.*

Aircraft De-icer Control

[For obvious reasons a condensed censor-passed press release is printed here in lieu of a technical description.]

MINNEAPOLIS, Aug. 31—Details of a new electronic device which signals and measures ice forming on airplanes in flight and automatically operates the plane's de-icers were made public here today. Called an "Ice Indicator," instrument will improve efficiency of Allied bombing planes, is result of laboratory research and flight tests over worst icing territory in U. S., marks a further advance in flying safety, was developed at instigation of commercial airlines and the U. S. Army Air Corps. An N.A.C.A. plane had been equipped with one of the new instruments since last fall. While most large commercial and bombing planes are equipped with rubber de-icers, problem has been to know when to start them operating, i.e., when the ice can best be cracked off. "Ice Indicator" provides pilot with information on thickness and rate of accumulation of ice on exposed plane surfaces. For first time in flying history de-icing equipment can be turned on at exact moment it becomes most efficient. Indicator is composed of three separate units and utilizes electrical principles for its operation. A pick-up plate or "sensing" element is mounted on wing or plane surface where ice acretion is to be measured. This plate, which is "very small," is set flush with the plane so as not to disturb the air foil. It contains parts which actuate the mechanism by noting the accumulation of ice. The disk is connected to an amplifier inside the wing, which in turn is connected to a power supply unit. The latter does the actual work of turning on the de-icers and registering accumulation on an instrument. Entire indicator, including amplifier and power supply unit, weighs less than 5 lbs. It was developed by Dr. Waldo Kliever, Minneapolis-Honeywell physicist [and author of recent *Instruments* articles].—*Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.*

If no two men have the same sense of touch—

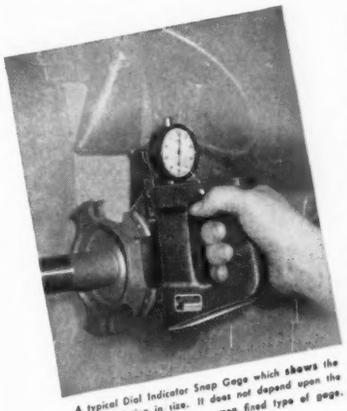
NEITHER HAVE FOUR

6-12 A.M.
Al's touch is tense and not always acute; it's a bit erratic.

12-6 P.M.
George works by "main strength". His touch is not sensitive.

6-12 P.M.
Bill really has a sensitive touch — except when he has a hangover.

12-6 A.M.
Massey is a human gage. But, he works only one out of four shifts.


A typical Dial Indicator Snap Gage which shows the exact variation in size. It does not depend upon the uncertain "feel" of the common fixed type of gage.

but . . . the quality of their inspection should not be influenced by the hours of their shift, their various nervous temperaments, their physical condition, or their general experience. And that will not do today.

Precision inspection of linear dimensions requires uniform, impersonal inspection. Gaging by the sense of touch requires skill without any recourse to magnification. Gaging by sight permits magnification of the error with greater **surety of uniform observation** of the error.

It also makes inspection faster by eliminating the period of doubt while the inspector "feels" the gage as it contacts the work. With a Federal Dial Indicator Gage he **sees** the error clearly and positively. It makes no difference whether the inspector is unskilled or simply tired or whether Bill is inspecting or Massey. A Federal Dial Indicator Gage magnifies the error to where it can be quickly distinguished.

Thousands of designs for faster, more accurate gaging of war material have been made by FEDERAL. Maybe one of them would help you. Why not find out?

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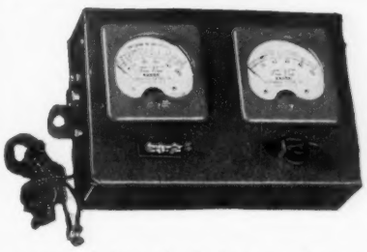

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(PIRANI TYPE)

Shown at left is meter box of our model No. 6 gauge.

This gauge successfully used by many of America's foremost manufacturers.

Send for circular on our new low priced D.C. operated gauge.

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INSTEAD OF RUBBER, COPPER AND OTHER STRATEGIC MATERIALS

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Flare type FITTINGS make it possible to install a complete system with no more tools than a sharp knife and a screw type flaring tool.

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Time Switch

New automatic time switch is described as "a simple, foolproof electrical timing device which should find many applications in industrial plants." It is arranged to close an electrical circuit after expiration of a predetermined time; but can be adapted for opening a circuit by simply reversing the position of the mercury switch element. When used on a-c. circuits, it has a capacity of 1200 watts, sufficient to control a 1-hp. motor of the repulsion induction type. Setting is accomplished by turning a knob to the time (AM or PM—up to 23 hours in advance) that the switch is to operate. A series connector with five feet of heavy-duty cord is supplied to simplify connections to plug-in types of electrical equipment. Installation is completed by fastening the timer to wall above electrical outlet, at a convenient height. Electrical circuits controlled by wall switches can be adapted for "timed" operation by removing the wall switch and installing Automatic Electrical Timer over the switch box.—*Philco Corp., Tioga and C Sts., Philadelphia, Pa.*

Photoelectric Reflection Meters

New "Model 600" and "Model 610" photoelectric reflection meters are designed for measuring reflectance and color of solid surfaces, fabrics, pastes, powders and opaque

liquids. They are provided with a "search unit" placed on the surface to be measured so that the test specimen need not be inserted into the instrument. Samples can be measured in rapid succession; may be of any size; and operator can easily select that part of the surface on which he wishes to take readings. Search unit (connected to instrument proper by a flexible cable) comprises light source and photocell. "Model 600" is operated from two dry-cell batteries housed in the instrument casing. Model 610 operates on 105-130-volt, 50-60-cycle a-c. supply. "Model 600" is recommended when general reflectance is to be measured and when instrument is to be taken to places where current is not readily available. "Model 610" is usable with more selective color filters, has higher sensitivity and registers dispersed reflection without responding to specular gloss. Three color filters (red, green, and blue) are furnished with the instruments. By using one filter selected for a particular test, it is possible to improve the spread of the readings so that differences hardly perceptible to the human eye are reliably registered. By using two or three filters on each sample, data are obtained which caracterize the color of the surface under test. Operation is simple and requires no training. Search unit is first placed on the standard in terms of which the readings are to be taken, and the needle is set on 100. Then, when search unit is placed on sample, needle indicates directly the reflectance of the sample in percent of the standard.—*Photovolt Corp., 95 Madison Ave., New York City.*

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Leaves no residue of
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Available . . .
in small bottles with applicator, as illustrated, or in 8 ounce, 16 ounce and gallon containers.

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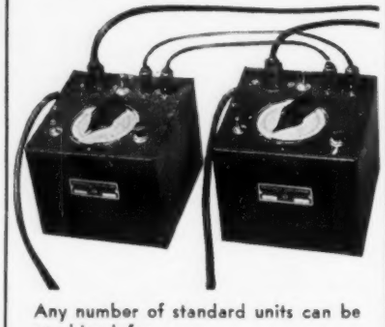
PHOTOVOLT ELECTRONIC TIMER

An adjustable timing relay operating without clockwork or motor.

- High speed timing, from 1/20 sec. up.
- Immediate automatic resetting
- Push button and remote control



Any number of standard units can be combined for
Sequence Timing and Recycling
in continuous operation.

For
Production and Process Control
Welding, Printing, Signaling
Laboratory Use and Life Tests

Write for literature
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95 Madison Ave. New York City

Thickness Tester for Plastics

New "Model M-25 Carson Electronic Micrometer," also known as "Carson Plastics Thickness Tester," is specifically designed for uniform thickness testing of all types of plastics and similar compressible materials. This portable instrument eliminates the human element in micrometer readings, hence eliminates doubt as to the thickness (to 0.0001") of any portion of tested material, whether extremely thin condenser sheets or heavy-weight bristol. The electronic circuit gives positive indication of setting point, independent of "feel" on dial. (See *Instruments*, Aug. 1941, page 224; Oct. 1941, page 321.) Thickness is read exactly as with a hand micrometer. Instrument operates from any 110-volt 60-cycle circuit. —*Instrument Specialties Co., 29 Peckman St., Little Falls, N. J.*

"Vernier-set" Timer

Recent design improvements are said to result in enhanced performance characteristics of "Series 2800 Vernier-Set Timers," for controlling machine and process operations. Previous standard built-in features of Telechron motor, simple knob setting without locking device, use of vernier scale for micro settings, ⅝" fine silver contacts, and hand adjustments to slides and bridges

for changing operating functions in the field, are now augmented with: (1) One-piece molded Bakelite terminal block accommodating all external wiring to clearly marked screw post terminals, as well as bridge positions for easy selection of desired Arrangement. (2) Leaf-spring contact for positive make-break action. (3) Timer and load circuits are now wired independently on all types; but, timer and load circuits can be wired together by simply placing an external jumper across L2 and C terminals. (4) Flaminol and special flexible wiring employed throughout. New Timers are available in two types: normal-clutch-action for resetting upon power failure; reverse-clutch-action for non-resetting on power failure. Dials may be selected from the following list: 15, 120 and 240 seconds; 10, 15, 30, 60, 120 and 240 minutes; 10, 20 and 60 hours. Variety of sheet metal housings for surface or flush mounting, as well as cast iron explosion-proof cases for one or two timers. Timer may be supplied interwired with one or more other timers, or with auxiliary equipment, mounted in a common case to carry out process schedules or handle loads in manners not provided by one timer. Standard units may operate from 110 or 220 volts, 25, 50 or 60 cycles. Load contacts are rated to carry 25 amperes at 110 volts, a.c., non-inductive.—*Automatic Temperature Control Co., Inc., 34 East Logan St., Philadelphia, Pa.*

The constant temperature water bath shown above is one of several models manufactured by E. H. Sargent and Company. The guaranteed uniformity of temperature throughout this bath is 0.01°C. This is possible because rapid circulation is obtained with a highly efficient central turbine driven by a Bodine motor.

This motor provides

DEPENDABLE POWER

for constant temperature water baths

A quiet, dependable motor is an important part of any constant temperature water bath. Uniformity of temperature is maintained by circulating the water smoothly and rapidly. Bodine motors were chosen by E. H. Sargent and Company for use on their water baths. Many other instrument manufacturers have also selected Bodine motors for their uniformly high quality.

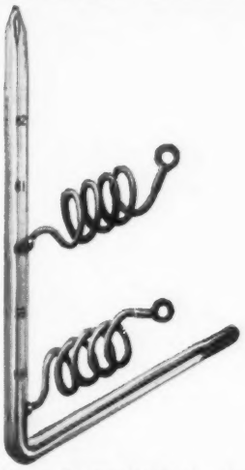
Careful selection of materials and high standards of workmanship are two good reasons why Bodine motors continue to provide trouble-free and reliable operation for many types of instruments in all kinds of service. Over 3000 standard specifications. Bodine Electric Company, 2244 W. Ohio St., Chicago, Illinois.

BODINE

BODINE FRACTIONAL HORSEPOWER MOTORS

For Extremely Close Temperature Control

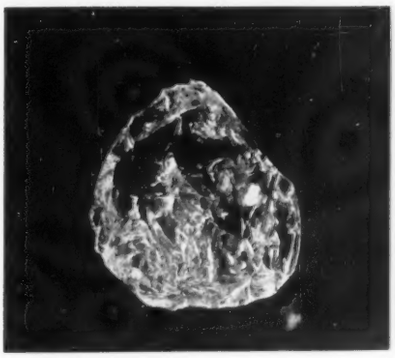
Visual-Stats



● Sensitivity of a hundredth of a degree is easily attainable. ● Top of mercury column visible at control point (where most important) because electrodes terminate at back of tube. No encircling metal bands! ● Available in angle form (illustrated) or conventional straight form. ● Send for brief, attractive bulletin.

The Philadelphia Thermometer Co.
915 Filbert Street -:- Philadelphia

Oldest Thermometer Manufacturer in Philadelphia



Crown Jewel for Victory

THIS is a chunk of optical glass. It has been broken out of a porcelain pot which came from the furnaces of the Bausch & Lomb Glass Plant.

It may be destined for use in binoculars—the long-range eyes of Army and Navy. It may be one of the types of glass that comprise the optical system of a medical research microscope. Or it may go into service as a range-finder prism, finished to accuracy limits of one second of arc, an error so small that it amounts to only one foot in 39 miles.

Fathered by William Bausch, the B&L Glass Plant was born in 1914. Under impetus of glass shortages in the first World War, it grew to full manhood. Research and development have continued without interruption since, so that today America need not look beyond her own borders for an adequate supply of this essential war material.

One hundred ten types of optical glass come regularly from the Bausch & Lomb furnaces, to provide the various refractive indices and dispersions required in the lenses and prisms for thousands of scientific instruments.

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OPTICAL CO. • ROCHESTER, NEW YORK
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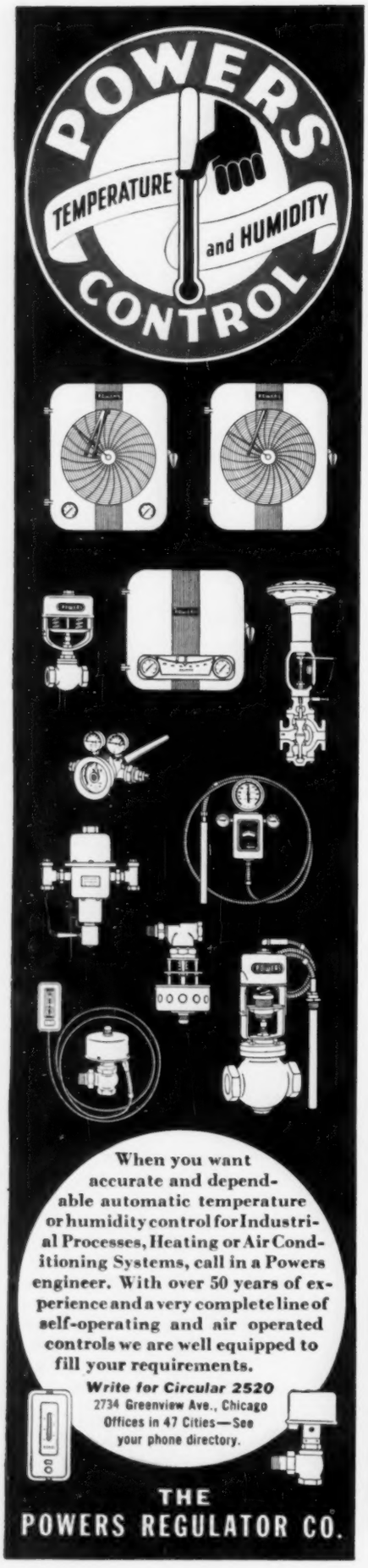
An American Scientific Institution Producing Optical Glass and Instruments for Military Use, Education, Research, Industry and Eyesight Correction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TEMPERATURE and HUMIDITY
CONTROL
When you want accurate and dependable automatic temperature or humidity control for Industrial Processes, Heating or Air Conditioning Systems, call in a Powers engineer. With over 50 years of experience and a very complete line of self-operating and air operated controls we are well equipped to fill your requirements.
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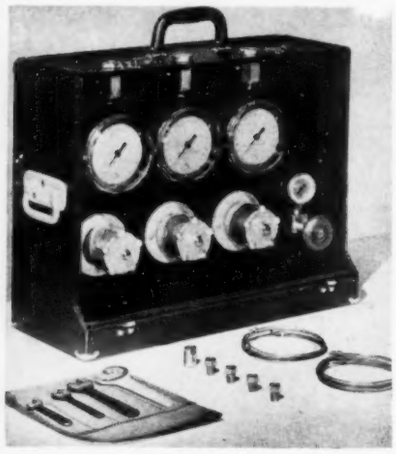
THE
POWERS REGULATOR CO.

Portable Pressure Gage Tester

New "Grove Gauge Comparator" permits all types of mounted service gages to be quickly and accurately checked "in-place" without breaking line connections, in a fraction of the time usually required. Time-saving is important whenever there is possibility of a gage having been damaged by momentary or sustained over-pressure, sud-



den pressure release, extreme vibration or shock. Equipped with three test gages accurate to 0.25% of full scale, Comparator will check gages with ranges up to 1000 lbs. Necessary testing pressures are supplied from built-in high-capacity air cylinders, which can be charged and recharged as often as required with any clean, dry gas. Close pressure control is made possible by three "Grove Pressure Loaders," mounted below the test gages. Loaders are accurate pressure reducers with built-in automatic relief. Large diaphragm-to-valve area ratio assures accuracy of delivery pressures, whether increasing, decreasing or constant. —*Grove Regulator Co., Oakland, Calif.*

Impact Test Machine for Enamelware

New Impact Test Machine has been standardized by the Enamel Utensil Manufacturer's Council. Fig. 1 shows the machine for standard two-quart size pans. The centering device and spring clamps are said to require minimal time for proper align-

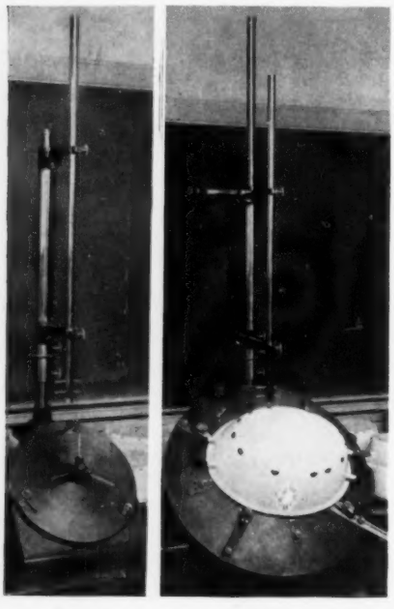


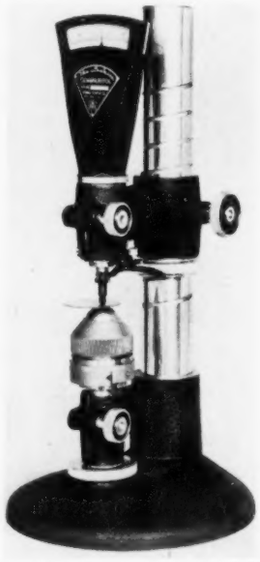
Fig. 1

Fig. 2

ment. Fig. 2 shows a modification of this equipment, which makes it possible to use the test on all sizes and shapes of ware. To change from Fig. 1 to Fig. 2 "takes but a few minutes." Test is made by dropping a duralium ball through a vertical tube, the height being controlled by means of removable pins through holes placed at 1" intervals in the tube. The pan is struck on the radius between the bottom and side; the direction of impact is 45°. This point is the most vulnerable from the standpoint of impact and is the one where failure in use is most likely to occur. Test procedure: ten points are struck on each pan, the disk is rotated and is graduated on the edge for equal spacing. Results are recorded in inches of height which the ball must fall to cause chipping. Five pans are tested and the results averaged and reported in inches. Consistent results and a wide range of quality for different enamels are said to be obtained when using this test. Ease of operation, simplicity of design and wide range of instrument are said to meet with popular approval by the industry.—*H. W. Mfg. Co., Urbana, Ill.*

Ball-shaped Measuring Anvil for Extremely Thin Work

New ball measuring anvil for use on the "Scherr Comparitol" (various models of which have been described in these columns) is designed to speed up, simplify and guarantee accuracy for the measurement of thin work, such as crystals, laminations, shims, extremely small gages, etc. It is said that the extreme thinness of this class of work makes it difficult, impractical and frequently impossible to obtain accurate readings in 0.0001" or 0.00005" by the use of the standard flat or serrated measuring anvil. With the ball anvil the work is placed between the flat feeler point and the round ball surface; and it is claimed that absolutely dependable results are obtained regardless of which part of the thin piece under inspection is being measured. It is said that all danger of distorting or bending the shim or lamination out of size a few ten-thousandths due to measuring pressure of the instrument is eliminated by the use of the measuring ball anvil. Another feature is that with the use of the ball anvil the instrument may also be used to check the flatness or parallelism of long thin pieces in all positions and on all parts of the work. The "Comparitol" column when used with this ball anvil is provided with an index line so that the ball point and feeler point can be lined up accurately from left to right as to center distance.—*George Scherr Co, Inc., 128 Lafayette St., New York City.*



★ A decade ago the cathode-ray oscillograph was a scientific curiosity. A few such costly instruments were in use, in leading laboratories, entrusted to skilled technicians.

Then came the first DuMont cathode-ray oscillograph. Simplicity, practicability, economy—those were the cardinal features. And those very features soon attracted universal attention. Thus the DuMont cathode-ray oscillograph became indispensable equipment not only in laboratories but also in factories and out in the field.

Today the DuMont name is synonymous with cathode-ray oscillography. That name is your assurance of the latest refinements in this firmly-established technique.

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DUMONT

ALLEN B. DU MONT LABORATORIES, INC.
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Portable Electrical Instruments

New "Model 625" d.c. and "Model 635" a.c. are added to maker's line of portables designed for today's rush of production testing or the rigid requirements of laboratory

checking. Instruments have 4.58" long hand-calibrated mirror scales, are housed in molded cases. Hinged cover closes when instrument is not in use. Detachable leather strap handle. Black molded case for d-c. instruments; a.c. case is red. Size is 6" × 5½" × 2½".—*The Triplett Electrical Instrument Co., Bluffton, Ohio.*

Self-contained Portable Ultraviolet Sources

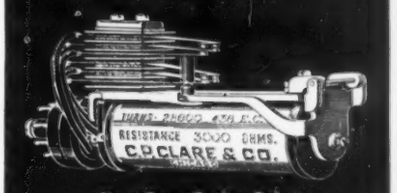
Announcement is made of a new and complete line of "Mineralight" ultraviolet sources (black-light lamps) for prospectors, miners, etc. Models range from powerful large outfits (carried on one's back in a pack-sack or pack-board) to "the smallest ever made." Fig. 1 shows five "Mineralight" lamps—the one at the right being a com-

Fig. 1

Fig. 2

plete outfit known as the "Midget Mineralight." Fig. 2 is a close-up of this model, which comprises lamp, tube, filter, transformer, flashlight, switch and battery, all in a 9¾" × 2¾" × 2¾" case. Weight with battery, 3¾ lbs.; without battery, 2¼ lbs. All new lamps are said to have higher efficiency, greater intensity of ultraviolet rays, new built-in features, etc.—*Ultra-Violet Products, Inc., 5205 Santa Monica Blvd., Los Angeles, Calif.*

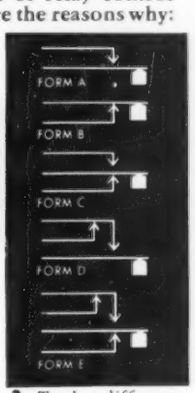
This CLARE Relay Can Take the Place of Many



Clare Type C d. c. Relay

■ **This rugged multiple-contact relay permits innumerable contact arrangements. Permits designing to small size, with a lesser number of relays; and facilitates maintenance. Adapted for use in electronic control devices and for sequence control and interlocking operations. Ideal where unusual arrangements of relay control are desired. Here are the reasons why:**

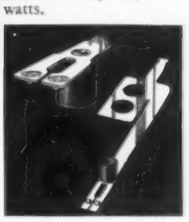
1. Contact springs employing any of the forms illustrated can be furnished.



2. Spring pile-up insulators of heat treated Bakelite which permit punching without cracks, have minimum cold flow and low moisture absorption content. Assembly locked together under hydraulic pressure. Withstands heavy breakdown tests.

3. Twelve different standard or special types and sizes of contacts can be furnished. Contacts are overall-welded to nickel silver springs. Sizes range from .062" silver, rated one ampere, 50 watts, to .1875" tungsten, rated four amperes, 500 watts.

4. Spring bushing insulators are Bakelite rod made by a patent process. Strong, hard, long wearing. Essential where heavy contact pressures are employed, where vibration exists, or heavy duty service is desired.



5. Armature assembly single or double arm. Has stainless steel shaft, operating in a marine brass yoke. Heel piece, coil core and armature are magnetic metal carefully annealed. Designed for d.c. service.

6. As illustrated, relay has octal base plug mounting for easy service and replacement. Other mountings, and Bakelite or metal cover, can be supplied.

• • •

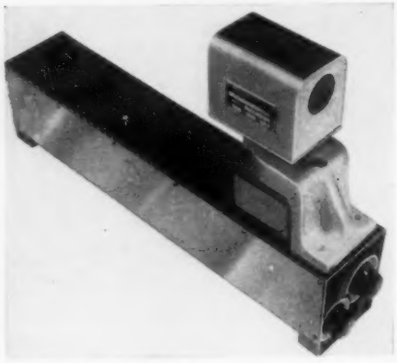
This relay is an example of Clare "custom-built" design and construction. Clare engineers can "custom build" a relay to meet your specific requirements—one that will reduce your overall relay cost and simplify your design problem. Write for catalog and data book. C. P. Clare and Co., 4719 West Sunnyside Avenue, Chicago.

CLARE RELAYS

"CUSTOM-BUILT" Multiple Contact Relays for Electrical, Electronic and Industrial Use

Registration Controller

New "Model B-16 Dual Scanner" is a complete and flexible photoelectric controller. Outstanding features are said to be: (1) Simplicity—One unit houses complete



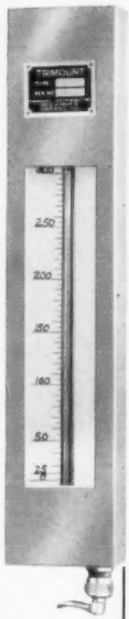
control, from light source through Dual Scanner and amplifier, to output connections from self-contained relay. All external wiring is reduced to one cable, plug-attached to one six-prong connector. (2) Flexibility—It is operated by either transmitted or reflected light, or both, and may be used with transparent, semi-opaque or opaque materials. Choice of operation is determined by a three-position selector switch. (3) Design and construction—Extremely compact unit, easily mounted and installed and as easily removed for service or replacement; so rugged as to function perfectly under rigorous demands of industrial use. Electronic tubes used in amplifier are inexpensive types obtainable at any radio store. (4) Operation is initiated by varying intensity of photo-tube illumination: In general practice a registration mark such as a spot, perforation or tab is imprinted on or contained in the material being processed. Its passage through Dual Scanner head produces a change in phototube current which, impressed upon amplifier, operates relay, thus causing action of a direct control device. Contacts are also provided for external connection to a limit switch actuated by a cam or other mechanical means to reset the control following each cycle of operation.—*United Cinephone Corp., Torrington, Conn.*

Outdoor-temperature-compensated Thermostat

Chief use of new "Econostat" is to regulate the heating system in apartment buildings, office buildings, hotels, factories, etc.

Intended for those installations which cannot be satisfactorily controlled from a single thermostat, it regulates the heating system of the building directly from the outdoor temperature by supplying the heat at intervals. It maintains the desired indoor temperature by varying the "heat on" periods in accordance with outdoor temperature changes. Thus, the heat supplied to the building is in proportion to the heat loss from the building and is not dependent upon the temperature in any particular room. It is readily installed in either new or existing buildings, and will control any type of heating system whether fired by a gas or oil burner, stoker, or central-station steam.—*Barber-Colman Co., Rockford, Ill.*

TRIMOUNT TANK LEVEL GAUGES



TRIMOUNT tank level gauges are designed for use with tanks from 3 to 60 feet high for indicating liquid level. They are supplied for optional use with a small hand pump or for connection to an air line. Scales are hand drawn on aluminum. Tubes are heavy wall Pyrex. Glass protection covers are standard. Range of sizes is from 12″ to 100″ standard. Standard finish is black crackle. Gauges are designed for panel mounting.

In requesting quotations on Trimount liquid level gauges be sure to specify if tank is vented or closed and type of fluid in tank.

Also complete line of Manometers and Indicating Flow Meters. Write for Catalog.

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IMPROVED AC-ME RECORDING GRAVITOMETER

For accurately recording the specific gravity of gas.

Contains no complicated rotating parts.

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Rugged construction requiring a minimum of maintenance.

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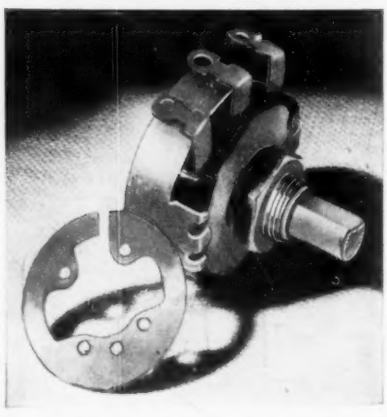
Ferrule Resistors

New ferrule resistor has been designed for easy interchangeability without the use of tools. An even winding of resistance wire on a ceramic core is protected by vitreous enamel coating. Wire terminates on metal bands or ferrules which permit mounting in fuse clips. Ferrules are cup, sleeve, or

cartridge type. Special ceramic cores are available which with special coating, will withstand temperature shock test of repeated immersions alternately from ice-water to hot water. Protective coatings which pass salt-water immersion tests are also available. New ferrule type resistor is particularly applicable for use in Navy, in Signal Corps, on Army aircraft and on railroads. Units can be supplied in accordance with Navy specifications. Wide range of sizes.—*Ohmite Mfg. Co., 4835 Flournoy St., Chicago, Ill.*

Non-wire-wound Resistors

Recent developments in the processing of resistive coatings are said to have resulted in "potentiometer" resistors and rheostats claimed to be virtually on a par with wire-



wound units in matters of resistance permanence, immunity to climatic conditions and wearing qualities. New "Series 37" units employ this new stabilized element in the form of a resistive coating on a Bakelite base, "practically as smooth and hard as glass." Element is chemically treated to prevent changes in composition; and heat-treated to stabilize temperature and humidity characteristics. It is said that leading instrument makers are using these units.—*Clarostat Mfg. Co., Inc., 285-7 N. 6th St., Brooklyn, N. Y.*

RUBICON PORTABLE PRECISION POTENTIOMETER

Available in a number of double-range combinations, such as 1 volt and .1 volt, 100 MV and 10 MV, also in pH ranges. Guaranteed accuracy .1%. *An outstanding value.*

Described in Bulletin 270 which also describes *Rubicon* High Precision Type B Laboratory Potentiometer.

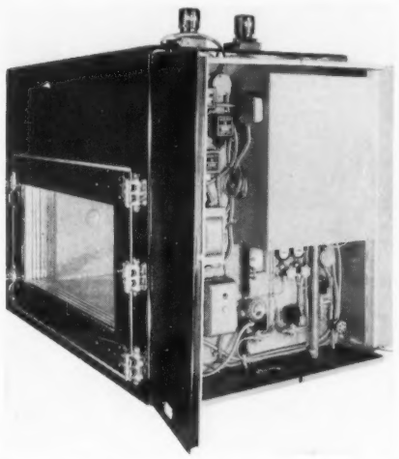
We also make galvanometers, electrometers, colorimeters, permeameters, Wheatstone and Kelvin Bridges, Resistance standards, coil testers, acronographs, clip-on transformer ammeters.

Descriptive bulletins available on request.

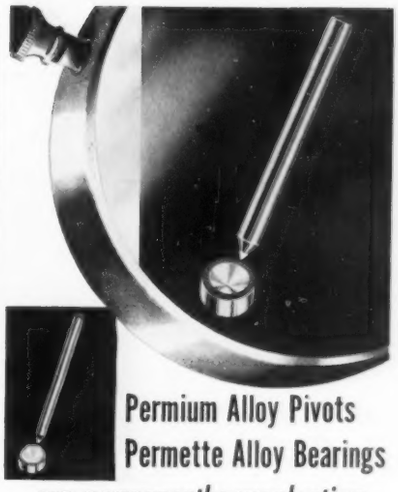
RUBICON COMPANY
Electrical Instrument Makers
Ridge Ave. at 35th St., Philadelphia, Pa.

Refrigerated Cabinets

Fully-automatic refrigerated testing chambers are announced, all adaptable to exacting laboratory or production-testing work. Illustration shows one with usable interior



dimensions approx. 59″ wide, 30″ deep and 28″ high (exterior 71″ × 42″ × 56½″ high). Temperature of -50°C. is attained in approx. one hour. At end of this cycle, if desired, temperature is raised to +70°C. A smaller cabinet, likewise in production now, has approx. inside dim. of 21″ wide, 24″ deep and 20″ high. Specifications for all cabinets (too lengthy for even abridged report here) seem to comprise every possible refinement. One item: Glass door has five glasses, dehydrated air between, thorough sealing, inner glass Libbey-Owens-Ford "Tuf-flex" tempered plate glass.—*American Coils Inc., 25 Lexington St., Newark, N. J.*



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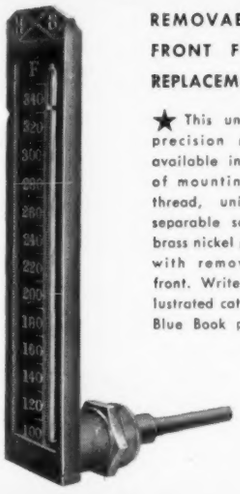
Volt-ohm-milliammeter

New "No. 423" general utility volt-ohm-milliameter is for production line tests and commercial laboratory measurements, is said to be used by the Signal Corps, in Army training schools "and other important wartime applications." The 3″ square indicator has a movement of 395 microamps. or a sensitivity of 2,500 ohms per volt, while the instrument has a uniform a-c.-d-c. voltmeter sensitivity of 1,000 ohms

per volt. Other features include an ohmmeter range of 10 megohms, each shunt and multiplier individually calibrated to a close tolerance, while all multipliers are individually matched in pairs so that the overall accuracy is within 1%. A suppressor type copper oxide rectifier is used for a-c. measurements and cabled or harness type construction is used throughout. "No. 423" is self-contained with necessary batteries and ready to operate, is available both in bench and portable models.—*Radio City Products Co., Inc., 127 W. 26th St., New York City.*

BRASS CASE INDUSTRIAL THERMOMETER



REMOVABLE GLASS FRONT FOR EASY REPLACEMENT

★ This unit, built for precision readings is available in three types of mountings — fixed thread, union hub or separable socket. Heavy brass nickel polished case with removable glass front. Write for fully illustrated catalog. Ask for Blue Book part 3.

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Interval Timers
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Time Switches
Relays

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AUTOMATIC ELECTRIC MANUFACTURING CO.
MANKATO, MINNESOTA

Chemical Proportioner

New "Graver Chemical Proportioner" feeds chemicals in proportion to the volume of water being treated, to an accuracy of 2% at all flows. Unlike previous models, it may be adapted to any standard fluid meter

which can be placed at any desired distance from the proportioner and chemical feeder. Any standard type of flow measuring device such as Venturi, orifice, propeller, or disk type meter, which can be equipped with a contactor, is placed in raw water supply line. Impulse set up by contactor (for predetermined amount of water) sets Proportioner into motion to lower swing pipe or skimmer into chemical solution thus feeding chemicals into treating plant in proportion to flow of water through meter. Proportioner consists of a standard make timer, relays, motor, reduction gear, and cable drum; all completely assembled in a control box which can be conveniently mounted on shell of chemical mixing tank. Timer is designed to operate motor drive of proportioner for a predetermined length of time for each impulse received from the meter contactor. By adjusting the "Variator," which is part of the timer, operator may vary amount of chemicals fed, by ±50%, in event quality of water requires change in treatment. Control box is fitted with a circular indicator graduated in percentage of available chemical remaining in chemical feeding tank. Proportioner is provided with a manual control, making it possible to operate feeder manually in event of failure of meter contactor; also an external manual control, whereby swing pipe may be lowered into chemical feeding tank, in event of electric current failure. An electric alarm signals when charge of chemical within the chemical tank, is exhausted.—*Graver Tank & Mfg. Co., Inc., East Chicago, Indiana.*

Limit Bridge for Production-line Resistance Tests

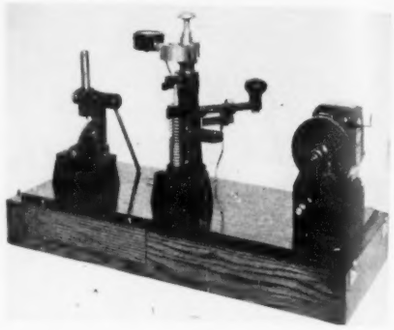
[Corrected description. Disregard the one in August issue.]

New "Electronic Limit Bridge Model No. 670" is said to make possible rapid resistance measurements within narrow tolerances. A direct reading is given of the percent deviation, plus or minus, of resistance values compared to any predetermined

standard. Dial is calibrated from zero center to 10% deviation on either side. With each main division on the dial indicating 0.5%, it is said that fractional divisions showing deviations of 0.1% can be read easily. Comparison is made against a predetermined internal standard, supplied as part of the bridge. Provision is made for using any other value of resistance desired by switching to "External Standard" and connecting the new standard value to the corresponding terminals. Component resistors are said to be accurate to 0.1%. Two Type 1C5GT tubes are used in the circuit. "Model No. 670" is battery-operated and completely self-contained.—*Radio City Products Co., Inc., 127 W. 26th St., New York City.*

Portable Spark Plug Testing Units

Two new portable test units "for the first time" permit accurate checks on the condition of both new and used spark plugs to be made in the field. They are completely self-contained and produce their own electrical current supply. Ignition troubles are frequently traceable not only to used plugs,



but also to new plugs which have just been installed. Without adequate testing facilities, the difficulty is not discovered until time has been wasted in investigating other possible causes or even hauling the engine back to its base. New test units eliminate these possibilities. Both units incorporate a hand-driven magneto. Air pressure is accumulated in the tester by means of a quick-acting hand pump.

(1) Type "P60-M554" (illustrated) includes, in addition to the self-contained testing equipment, an electrode forming and adjusting tool. Spark plugs found to be satisfactory electrically can be properly adjusted on the spot and returned to the engine for further service. This unit is mounted in a box, with a drawer in the base for tools. A cover with carrying handles is provided. Unit is completely wired, ready for instant use. Overall dimensions are 24" long by 10½" wide by 16¼" high. Weight, approx. 60 lbs., including tools.

(2) Type "P40-M554" provides spark plug testing equipment only. It is provided with the hand driven magneto and BG Model 554 spark plug tester as described above. It is installed in a metal box with hinged top and carrying handles. Overall dimensions 9" × 16" × 16". Approx. weight 40 lbs.—*Pacific Airmotive Division, Burbank, Calif.*

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No purchase today can be overlooked for each thermometer that gives you smooth running production is a big asset in any plant. Delays for breakage are costly.

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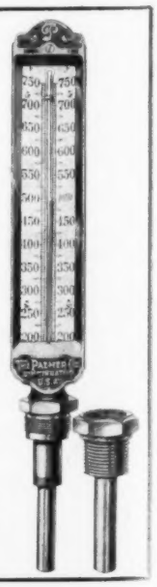
(Catalog No. 300-D sent promptly)



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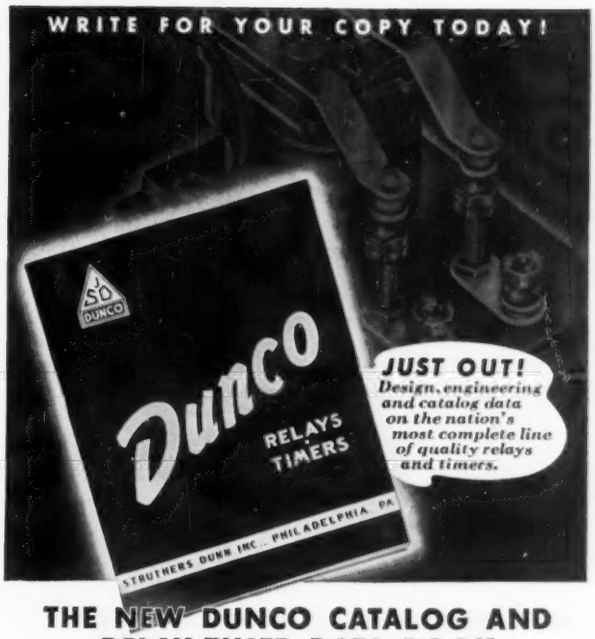
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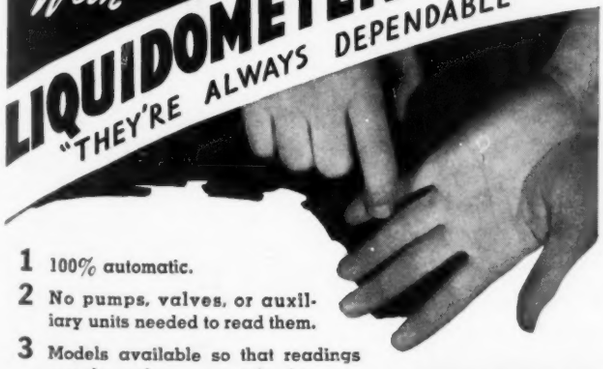

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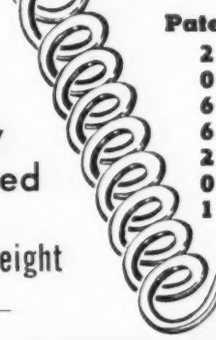

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DYNAMIC UNBALANCE

(Continued from Page 365)

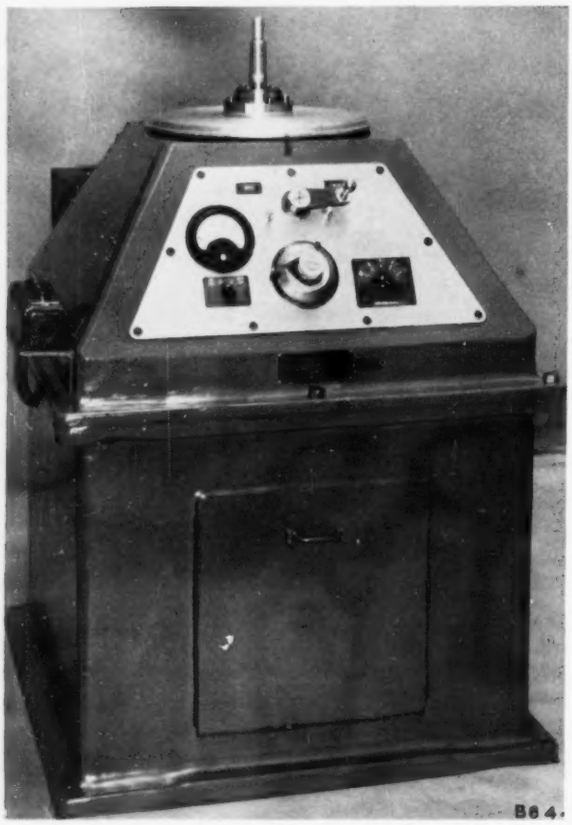

Fig. 14

A modification of the Type EO just described is the *vertical static balancing machine*, Fig. 14, which is suitable for such parts as pulleys, fly-wheels, clutches, fans, etc., which are narrow with respect to the diameter and require only a static correction. The part to be balanced is mounted on the adapter at the extreme upper end of a vertical spindle carried in a vibratory frame that can be best likened to a swinging door with the hinges along one of the vertical edges. The spindle is mounted along the free side. Static unbalance in the part rotating with the spindle sets up vibrations about the hinged side and causes an alternating voltage to be generated in a magnetic pick-up as explained previously. The same type of commutator is used to rectify the output from the pick-up so that it will deflect the d-c. microammeter located in the panel. The angle of unbalance is shown on the commutator dial and this angular reading is simply transferred to the angle reference disk at the top of the machine to locate either the heavy or light spots on the work, depending upon the method used for correction. The lever at the top of the panel is for locking the vibratory frame when loading or unloading the machine. Adapters of various types can be interchanged. This machine is fast, extremely simple, and otherwise suitable for the production line.

Another rather interesting modification of the indicating type of dynamic balancing machine is shown in Fig. 15. It was developed for balancing fluid couplings after assembly with the crank shaft. Individual members of this assembly are balanced before being assembled but it is necessary to balance again after assembly when the coupling is filled with liquid.

The entire assembly (crank shaft, coupling, housing, and clutch) is mounted on a vibratory cradle as previously explained. However, since the clutch member of this assembly is connected to the crank shaft and coupling member only through a liquid medium, this floating member must be driven individually during the balancing operation to keep it running in phase with the crank shaft and coupling. To accomplish this, a special drive extends through one of the hollow cradle tubes to the tail end of the machine, where it connects through a universal joint driving rod to the vibratory cradle, and eventually to the floating member of the assembly through two flexible drive pins. The head end of the cradle is of usual construction, using a universally jointed driving rod and drive pins connecting to an adapter on the timing gear end of the crank shaft. At each end of the cradle a magnetic pick-up converts the vibration of the cradle to an a-c. output.

In this machine the headstock construction is rather unique. In order to align the axial planes of unbalance in the two members, an electronic unit is employed for rectifying the output of the pick-ups without regard to the angle of unbalance. The hand-wheel at the front of the machine connects in effect to a differential arrangement in the drive to the tail end of the machine, consequently to the floating member of the assembly. While the machine is running, if this hand-wheel is turned the floating member of the assembly will be shifted in one direction, or the other, with respect to the coupling and crank shaft assembly. If there is an unbalance in the floating member and another in the coupling, and if the two unbalances are brought into the same axial planes, the microammeter will read a maximum. The operator, therefore, first turns the hand-wheel slowly in either direction, watches the pointer and stops when a maximum reading is obtained. He knows then that the two unbalances are together. The next procedure is to obtain the actual values of each of the two unbalances. To do this he switches over to the commutator which is similar to that previously described. When the microammeter is on the commutator circuit, the electronic system is not in use, and the commutator is used in the regular manner to determine both the angle of unbalance and the maximum amount, which in this case is the sum of the two unbalances. The maximum reading taken with the

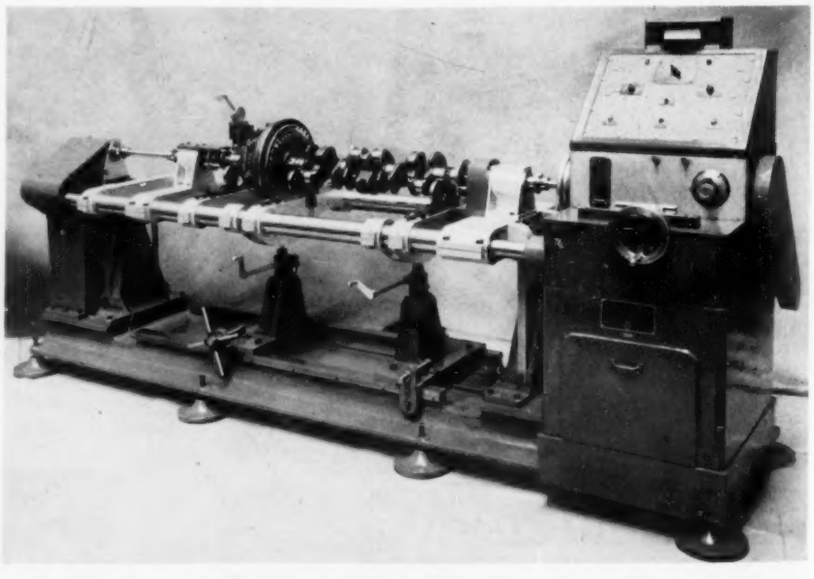

Fig. 15

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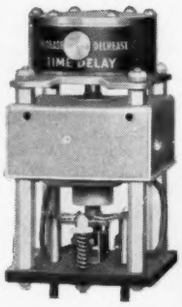

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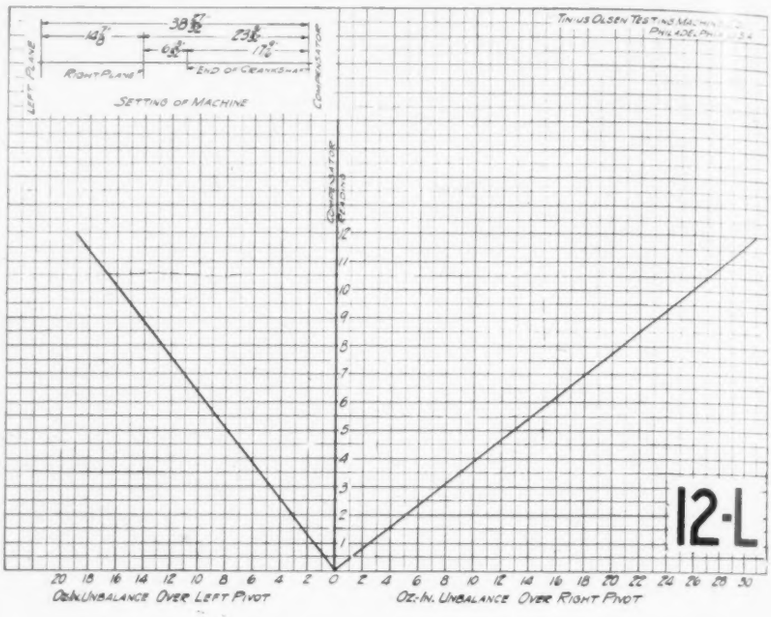
commutator is noted and then, leaving the commutator set for the position of maximum reading, the operator turns the hand-wheel until the floating member of the assembly is turned exactly 180° from the position of maximum reading. (An indicator just back of the hand-wheel shows the operator when he has turned the floating member 180°.) Now the reading is the difference between the two unbalances.

The operator then stops the machine, turning the assembly until the angle shown on the reference disk on the spindle corresponds to that on the commutator dial. The assembly then is in position for correction. (On the particular machine illustrated this was done by welding slugs on the coupling and by drilling holes in the edge of the pressure plate of the clutch which is a part of the floating member. The spot welding machine and drill press were mounted on the space provided at the back of the machine but are not shown in this photograph.) Both corrections are applied from the top and, since one unbalance was turned 180° from the other, both members of the assembly are in the correct position, when the machine was stopped, for the application of corrections: one by adding metal and the other by removing metal.

The actual values of the corrections are determined from the values of the maximum and minimum readings. The actual unbalance in the coupling member is half the sum of the maximum and minimum unbalances as indicated on the microammeter; the unbalance in the floating member is half the difference of the maximum and minimum unbalances. A chart was prepared for converting microammeter readings to actual corrections in either slugs to be welded or holes to be drilled.



LEFT END
RIGHT END
12-M
DRILL POINT
SETTING OF MACHINE
DEPTHS ARE IN INCHES AND ARE MEASURED TO THE POINT OF THE DRILL
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DRILL CHART FOR USE ON A 25 OLSEN STATIC DYNAMIC BALANCING MACHINE
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METHODS OF PRODUCTION CORRECTIONS

When corrections for unbalance are done on a production basis, some type of chart is generally used. The make-up of a chart depends upon a number of factors, including the design of the part, method of correction, accuracy of balance required, balancing machine characteristics, etc. If corrections are to be made by removal of metal, probably the fastest and most accurate method is by drilling, since the amount of material removed can be accurately controlled by regulating the depth or number of drilled holes. Grinding is sometimes used for removing material, but this method leaves entirely up to the judgment of the operator how much is being removed, so that ordinarily it is not so satisfactory for production work.

If weight is to be added it can be done by welding on slugs, adding solder, bolting or riveting on weights, or other methods. In the case of small armatures, corrections are usually made by pushing small slugs of the proper length into the armature slots. These slugs are an extruded or rolled shape to suit the particular armature slots and are cut to various lengths.

Let us look at representative charts so as to obtain some idea as to how they may be made up. Remember however that there are many different ways in which correction charts may be arranged, and each type of part requires its own analysis, taking into consideration all of the factors in any way connected with correction of the part.

The simplest kind of a chart is a line chart, such as "12-L." This type of chart may be used for either the addition or removal of metal and simply converts the machine reading to actual ounce-inches of unbalance in either the left or right correction plane. The corresponding amount in ounces to be added or removed is found by dividing the chart value in ounce-inches by the radius to the points of correction in inches. This type of chart is suitable for work that can be corrected at any point around its entire periphery, but whose radius may vary from the center of the shaft to the point of correction.

When the radius to the point of correction is constant a chart such as "12-M" is preferable. It shows, for a given machine reading in either plane, the actual depths of drilled holes in thousandths of an inch, and the number of such holes required to bring the part into perfect balance. It should be noted, however, that such a chart is good only for one size of drill and for one particular machine setting, which means that it is applicable to only the part for which the chart was originally calculated.

In preparing drill charts such as this, it must be remembered that the unbalance correction is based on the radius to the center of gravity of the drilled hole multiplied by the weight of the metal removed by this hole, so that when drilling is done radially or at an angle with the axis of the part, the radius to the center of gravity at the hole con-

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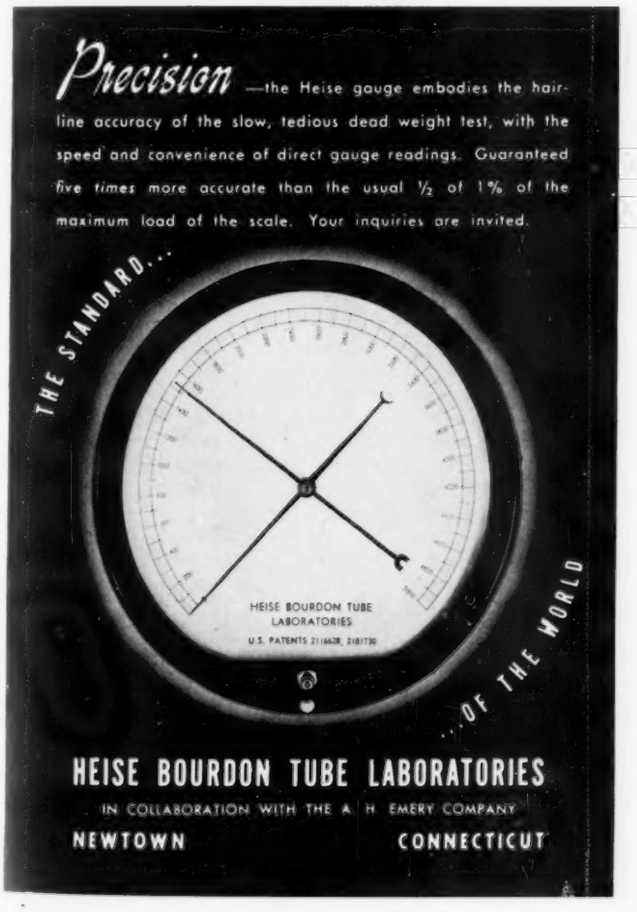
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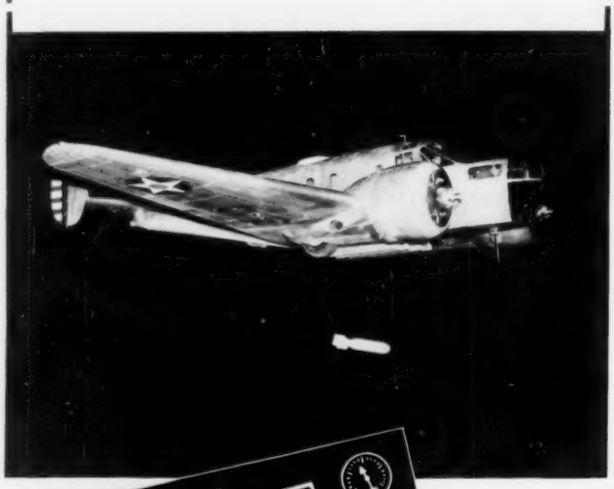

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tinually shortens depending upon the depth of the hole and consequently the unbalance to be removed. This shortening of the radius must be taken into account as well as the shifting of the center of gravity of the drilled hole caused by the point of the drill. The effect of the point is naturally less for a deep hole than for a shallow hole, but this effect is very important and must be considered when making up correction charts.

Another type of chart can be prepared to take care of component drilling, that is, where it is not possible to drill out metal at the exact spot indicated by the machine, but where corrections must be made in adjacent points in order to balance the part. Such a case is taken care of by a chart* which was made up for a crank shaft where corrections were made by drilling in the pins in conjunction with the cheek, or counterweight, at each end of the shaft. This chart is laid out with the machine readings for the left correction plane in the left column and the right correction plane in the right column. Angular locations are along the top and bottom of the chart and cover a spacing of 240° of the circumference, which is all that can be taken care of in this particular case. That is, the chart covers corrections for unbalance occurring anywhere between, for instance, number one pin and the counterweight and then between the counterweight and number two pin. (Still another chart is required to take care of the angle between the number two pin and number one pin.) The body of the chart shows the depths of drilled holes in thousandths of an inch in both the pin and the counterweight to bring the shaft into balance for a given machine reading. Note again that this chart is made up for a given setting of the machine, depending upon the part being balanced, and also made up for definite sizes of drills to be used in counterweight and pins, so that it is not good for any other part.

Such charts are tedious to figure but, once prepared, facilitate corrections on a real production basis.

*Not reproduced: it is about six times the size of "12-L" or "12-M" and would take a whole page. This portion of Mr. Lawrie's lecture has not been abridged, however, for it conveys an adequate description of the chart.—EDITOR.